PRE OPERATIVE AND POST OPERATIVE COMPARISON OF PATIENTS WITH BENIGN VOCAL CORD MASS LESIONS WITH STROBOSCOPY, VOICE ANALYSIS AND VOICE HANDICAP INDEX

PRE OPERATIVE AND POST OPERATIVE COMPARISON OF PATIENTS WITH BENIGN VOCAL CORD MASS LESIONS BY STROBOSCOPY, VOICE ANALYSIS AND VOICE HANDICAP INDEX

DISSERTATION SUBMITTED IN PART FULFILLMENT OF THE

RULES AND REGULATIONS FOR THE

M.S. (BRANCH IV) OTORHINOLARYNGOLOGY

EXAMINATION OF

THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY

TO BE HELD IN

FEBRUARY 2007

CERTIFICATE

This is to certify that the work presented in this dissertation, in partial fulfillment of the **Degree of MS Branch IV (ENT)** examination of **THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY** Chennai entitled "**PRE AND POST OPERATIVE COMPARISON OF PATIENTS WITH BENIGN VOCAL CORD LESIONS BY STROBOSCOPY, VOICE ANALYSIS AND VOICE HANDICAP INDEX**" is the bonafide work of **Dr.George Thomas,** post graduate student in MS (ENT).It was carried out and prepared under my overall guidance and supervision in the Department of Otorhinolaryngology and Head and Neck Surgery, CMC , Vellore

Guide:

_____

Dr RUPA VEDANTAM MS, DLO

Professor and Head of Department

Department of Otorhinolaryngology and Head and Neck Surgery

CMC, Vellore.

ACKNOWLEDGEMENTS

I thank GOD almighty for supporting me in each step.

I wish to express my deep gratitude to *Dr. V.RUPA*, Professor & Head of the Department of ENT, CMC Hospital, Vellore, for her able guidance and encouragement in conducting this study and especially so in fine-tuning this dissertation.

I am extremely grateful to *Dr. SUMA SUSAN MATHEW*, senior lecturer, Department of ENT, not only for being my co-investigator but also for being a constant inspiration.

Miss Shipra B Chrysolyte for being my Co-investigator in this study and for her valuable help.

I am extremely thankful to *Dr. ANAND JOB, Dr. ACHAMMA BALRAJ, Dr. JOHN MATHEW,* Department of ENT, and all the units, CMC. Vellore who allowed me to review the patients in units and for their valuable advices and help.

I am expressing my gratitude to all the staff in the Department of Audiology and the Department of Biostatistics for their services.

I wish to thank the *Fluid Research Committee*, CMC, Vellore for granting me financial assistance for conducting the study.

Last, but not the least, I wish to thank my wife Anulekha Mary John whose constant support made this dissertation a reality.

CONTENTS

Introduction

Benign vocal cord mass lesions such as polyps, nodules and cysts affect voice production. They occur secondary to voice abuse or due to chronic sinusitis and laryngopharnyngeal reflux. These conditions lead to chronic inflammatory changes in the vocal cord which can progress to polyp or granuloma formation. The diagnosis of these conditions may be made by indirect laryngoscopy or flexible nasopharyngolaryngoscopy. The objective measurement of the degree of pathology in the vocal folds is performed by using various parameters of videostrobosocopic examination. A comparison of pre operative and post operative changes in the vocal folds can show the degree of improvement. Voice analysis is another method of subjectively assessing the voice changes produced by pathologies affecting the vocal cord. Videostrobosocopic examination may also be combined with analysis of voice parameters assess the improvement or worsening of voice after surgery.

The present study is aimed at examining the objective and subjective parameters using stroboscopy, voice analysis and VHI of patients undergoing surgery for vocal fold lesions which are benign in nature.

Aims and Objectives

1. To compare the pre and post operative changes in the voice of patients with benign lesions of the vocal cord using stroboscopy.

2. To compare the pre and post operative changes in the voice of patients with benign lesions of the vocal cord using voice analysis.

3. To assess subjective improvement of their voice after surgery using the voice handicap index pre and post operatively.

Review of literature

Embryology (Fig 1)

The larynx is developed from the midline ventral respiratory diverticulum of the foregut known as the laryngotracheal groove. The groove appears posterior to the hypobranchial eminence. This portion of foregut posterior to diverticulum becomes oesophagus. The groove deepens and its edges fuse to form a septum. The laryngotracheal tube formed fuse caudally and extend cranially. The upper end remains separate to communicate with the pharynx. The lower portion elongates and divides, and divides dichotomously to two lobes and forms the bronchi. The portion above the division becomes trachea and uppermost portion becomes the larynx. The epiglottis develops from the posterior part of hypobranchial eminences. The thyroid cartilage develops from the fourth arch cartilage. Other cartilages and trachea are from fifth and sixth arch cartilage. The fourth arch nerve is superior laryngeal nerve and the sixth arch nerve is recurrent laryngeal nerve.[1,2]

The larynx is an extraordinary versatile organ capable of many rapid and subtle adjustments and capable of sound production over a wide range of pitch and loudness. The structural framework of the larynx is consisting of nine cartilages, their connecting membranes and ligaments.

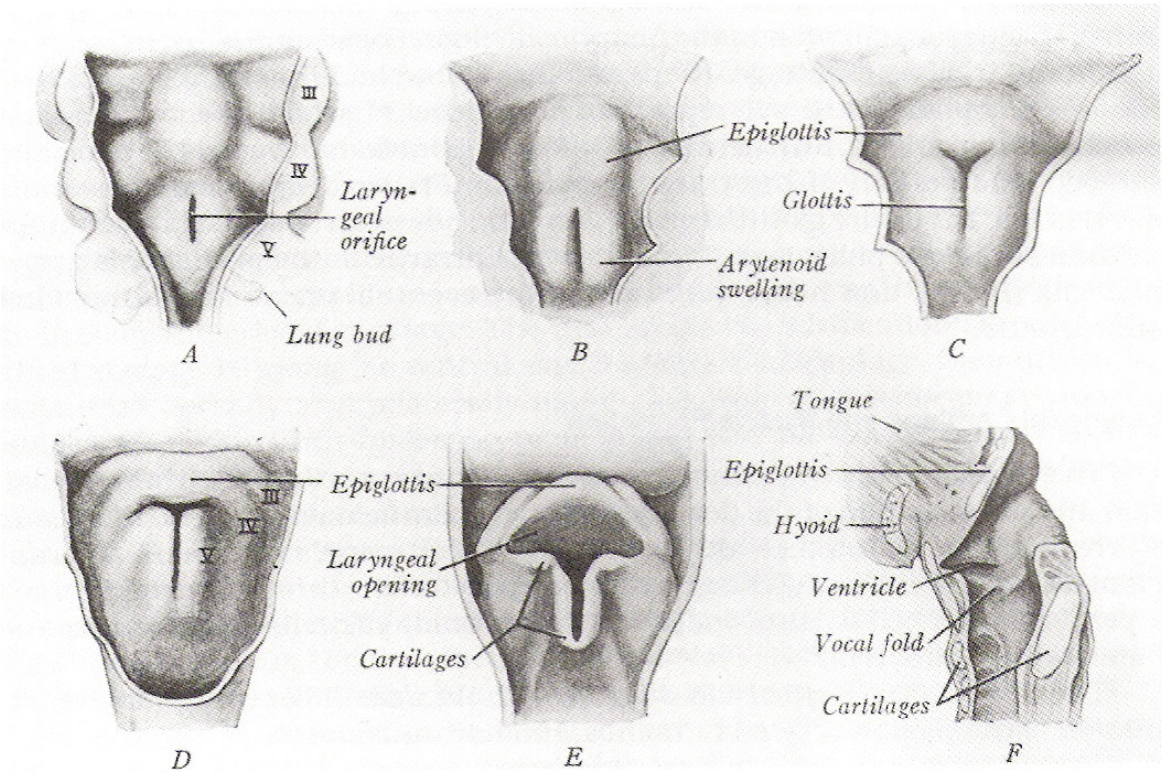

Fig 1 Embryology of larynx

Cartilages of larynx (fig 2,3)

Thyroid cartilage

This consists of two pentagonal plates that meet anteriorly in the midline at an angle of 90 degree and 120 degree in female and male. It is of funnel shaped in men and cylindrical in female. Thyroid cartilage is covered by outer thick perichondrium and inner thin perichondirum. Attachment of the anterior commisure of vocal cord lacks perichondrium.

Cricoid cartilage

This is a signet ring shaped cartilage, with a thin anterior arch and a broader posterior lamina about 20 to 30 mm high. The cricothyroid membrane connects the thyroid with cricoid. In the anterior part this membrane is thickened and it is called the cricothyroid ligament. The inferior part is firmly attached to the trachea and superiorly, the lamina has facets for articulation with the arytenoids cartilage. This forms a crucial joint in the production of voice.

Epiglottic cartilage

It is a leaf like hyaline cartilage whose anterior surface projects above the thyroid cartilage and faces the base of tongue and lingual tonsils. The inferior portion is narrower than the upper part. Thyroepiglottic ligament connects it to thyroid cartilage and hyoepiglotttic ligament connects it to the hyoid superiorly. Along the inferior aspect of the laryngeal surface of the petiole the epiglottic tubercle partially overhangs the anterior commisure.

Arytenoid cartilages

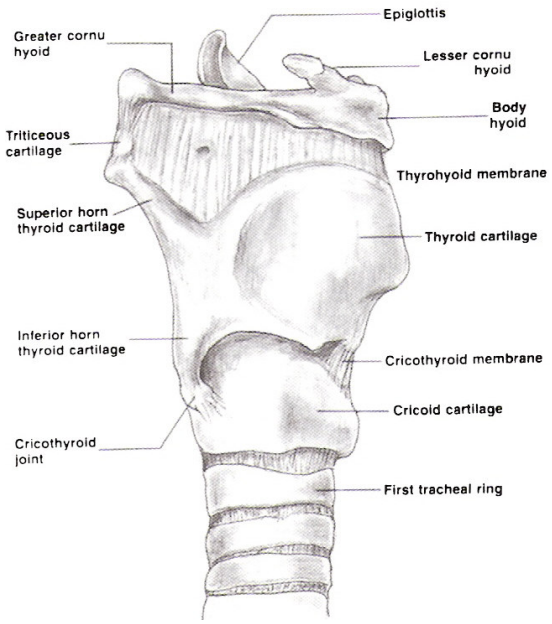

Fig 2 Cartilages, membranes and ligaments of larynx

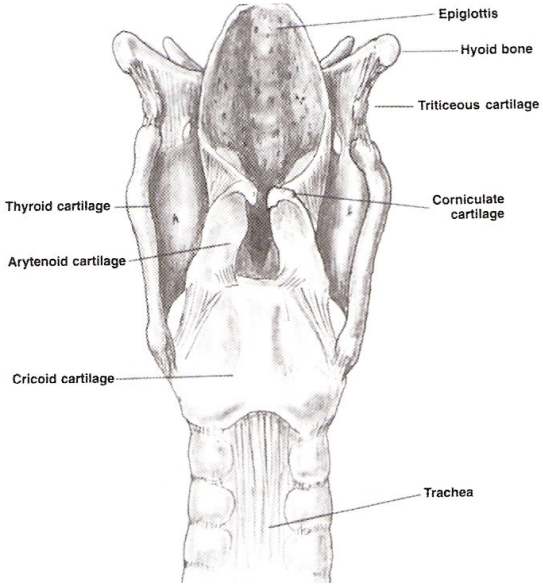

Fig 3 Cartilages, membranes and ligaments of larynx posterior view

These are paired pyramidal cartilage which rests upon the cricoid lamina with two processes (vocal and muscular) an apex and a base. The concave base articulates with the cricoid cartilage in a synovial joint.

Minor cartilages:

The corniculate cartilage (cartilage of Santorini) is located just above the apices of arytenoids. The cuneiform cartilage (cartilage of Wrisberg) is found in the superior aspect of the aryepiglottic folds. These cartilages provide rigidity to the membranes, which function as ramparts that guides the food bolus away from the larynx.

Ligaments of larynx

Quadrangular membrane

On both side of larynx, the membrane extends from the lateral edge of the epiglottis to the arytenoid cartilage posteriorly. The superior border of the membrane is a free edge corresponding to aryepiglottic folds, which extends posteroinferiorly from the epiglottis to the corniculate cartilage. Each membrane's lower edge is also free and it extends from the epiglottis to the vocal process of the arytenoids corresponding to the false vocal cords which is also known as the ventricular bands. The superior and inferior edges of this membrane are thickened giving rise to the aryepiglottic ligament and the vestibular ligament respectively.

Triangular membrane (conus elasticus):

The triangular membrane is paired and together forms the conus elasticus. Its inferior edge is firmly attached to the cricoid cartilage. Its base is located anteriorly attached to both thyroid and cricoid cartilage. Each membranes apex is attached to the vocal process of arytenoids. The free superior edge of this membrane is forming the vocal ligament. The anterior end of the vocal ligament is attached to the thyroid cartilage forming the anterior commissure tendon or called the Broyles ligament. Anteriorly the thick part of the conus elasticus forms the cricothyroid ligament.

Mucous membrane:

It is continuous with the lining of pharynx above and the trachea below. This membrane is particularly rich in mucous glands in the region of the laryngeal ventricle (ventricle of Morgagni). It is closely adherent to the epiglottis, the aryepiglottic ligament and the vocal cords. The epithelium of larynx is either squamous, ciliated columnar or transitional. The upper half of the posterior surface of the epiglottis , the upper part of the aryepiglottic folds. The posterior commissure and vocal cords are covered by squamous epithelium.

Laryngeal muscles:

The laryngeal muscles can be divided into three groups: intrinsic, extrinsic, and accessory.

Intrinsic muscles: (Table 1, Fig 4)

The intrinsic muscle of the larynx may be classified according to their effect on the shape of glottis and the vibratory behavior of the vocal fold. They are adductors, abductors, relaxers and tensor muscles.

The articulation between the cricoid and arytenoid cartilages is a complex one, involving sliding of arytenoid and rotation about its vertical axis. Arytenoid movement is the composite of all the actions of the intrinsic muscles acting together.

TABLE 1[3]

Function of Laryngeal Muscles in Vocal cord Adjustments·

	CT	VOC	LCA	IA	PCA
Position	Paramedian	Adduct (Membranous portion)	Adduct (Entire fold)	Adduct (Cartilaginous portion)	Abduct
Level	Lower	Lower	Lower	--	Elevate
Length	Elongate	Shorten	Elongate	(Shorten)	Elongate
Thickness	Thin	Thicken	Thin	(Thicken)	Thin
Edge	Sharpen	Round	Sharpen	--	Round
Cover	Stiffen	Slacken	Stiffen	(Slacken)	Stiffen
Transition	Stiffen	Slacken	Stiffen	(Slacken)	Stiffen
Body	Stiffen	Stiffen	Stiffen	(Slacken)	Stiffen

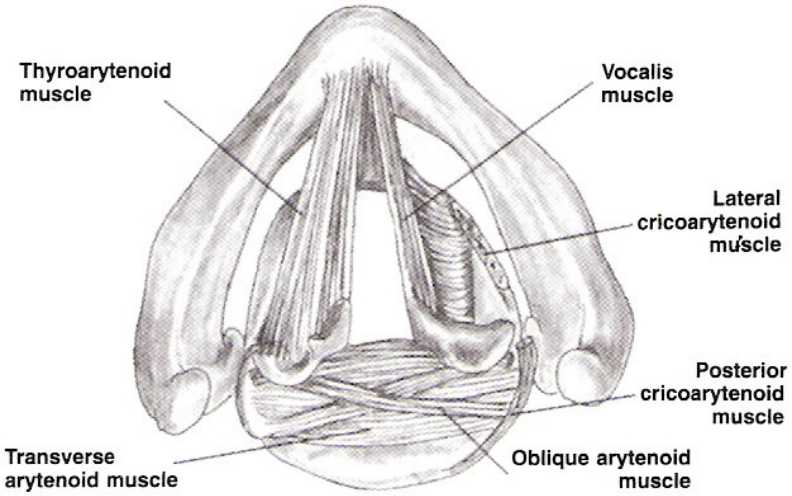

Fig 4 Intrinsic muscles of larynx.

The Posterior Cricoarytenoid Muscle (PCA)

The posterior cricoarytenoid is the sole abductor of the vocal folds. This muscle originates from the back of the cricoid cartilage and inserts into the muscular process of the arytenoid cartilage. The PCA of the human is composed of two compartments, vertical compartment, which inserts onto the lateral aspect of the muscular process of the arytenoid, horizontal compartment, which inserts onto the medial aspect of the muscular process of the arytenoid cartilage. In the human each of these compartments usually receives its own nerve branch from the recurrent laryngeal nerves. This nerve branch innervates only one compartment with little overlap between them. Anatomically, these compartments can almost be considered separate muscles. The vertical and horizontal compartments of the PCA may have different functions.

The role of the whole PCA during phonation is controversial. It is widely accepted that the PCA pulls the vocal folds apart after voicing. The role of the PCA during voicing is less clear.

The Interarytenoid Muscle (IA)

The interarytenoid muscle is an unpaired muscle that originates from the back of each arytenoid cartilage. It approximates the posterior ends of the arytenoid cartilages, thus playing an important role in both the phonatory and the sphincteric mechanisms of the larynx.

The lateral Cricoarytenoid Muscle (LCA)

The lateral cricoarytenoid muscle originates from the cricoid arch and inserts onto the muscular process of the arytenoid cartilage. Contraction of the muscle adducts the vocal folds.

The Thyroarytenoid Muscle (TA)

The thyroarytenoid muscle is the most important muscle for phonation. This muscle is composed of two basic compartments: a medial part, the vocalis, which is more involved in phonation; and a lateral part, the muscularis, which is more involved with adduction. Depending on the myofibrillar ATPase reaction, divides muscle fibers into a fast and slow type. These slow fibers are arranged in a gradient with the medial edge of the muscle approaching 100% slow twitch and gradually changing into almost 100% fasttwitch at the lateral edge.

Extrinsic muscles:

The cricothyroid muscles are located on the exterior surface of the larynx, each consist of two parts. Their anterior horizontal portion arises from the superior edge of the cricoid arch and inserts upon the posterolateral border of the thyroid cartilage. The oblique portion extends from the lateral surface of the cricoid cartilage to the inferior edge of the thyroid cartilage.

The cricothyroid muscle tilts the larynx by approximating the cricoid and thyroid anteriorly utilizing the cricothyroid joint. The cricothyroid muscle stretches the vocal fold, this muscle thins the vocal fold and sharpens its edge. These characteristic changes produced by the cricothyroid muscles in the vocal folds indicate

that the cricothyroid muscles are an important determinant of the pitch of the acoustic signal of the vibrating vocal folds.

Accessory muscles:

The accessory muscles can be divided into elevator and depressor groups. The first group includes the digastric (both bellies), the stylohyoid, the geniohyoid, and the mylohyoid muscles, all of which act to pull the larynx superiorly. Additionally, contraction of the hyoglossus muscle elevates the larynx if the remainder of the tongue musculature remains fixed. The depressor muscles include the sternohyoid, sternothyroid, and omohyoid muscles, which all pull the larynx inferiorly. The thyrohyoid muscle pulls the hyoid bone and thyroid cartilage together.

Laryngeal neuromuscular anatomy: (Fig 5, 6)

The larynx is innervated by two main branches of the vagus nerve: the superior and recurrent laryngeal nerves. The superior laryngeal nerve (SLN) branches off the vagus high in the neck at the inferior end of the nodose ganglion and bifurcates into two nerves: the internal and the external. The internal enters into the larynx at the thyrohyoid membrane and supply the sensory innervation to the entire mucosa of the larynx above the vocal folds. The external SLN passes down the front of the larynx to supply motor innervation to the cricothyroid muscle. An extension of this nerve passes inside the larynx and may supply motor and sensory innervation to the vocal folds.

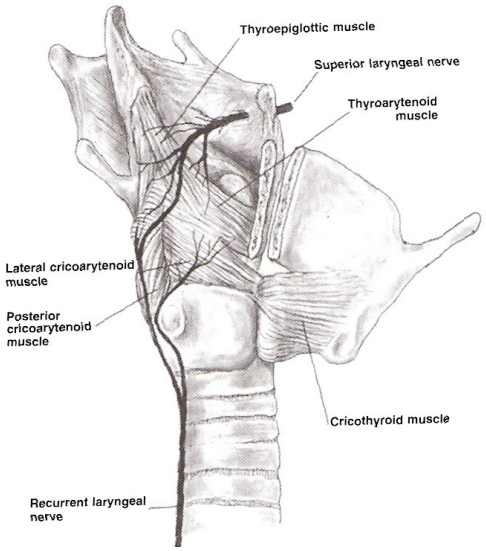

Fig 5 Nerve supply of larynx

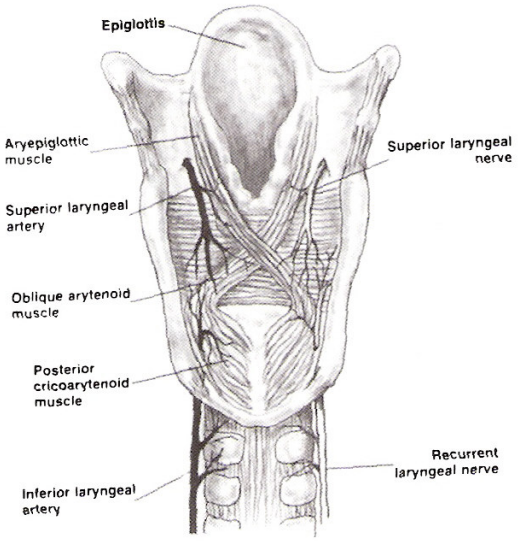

Fig 6. Nerve supply of larynx.

The recurrent laryngeal nerves are the main motor innervation to the larynx. The recurrent laryngeal nerves have an unusual course. They travel with the vagus nerve into the chest before branching. On the left, the recurrent laryngeal nerve usually loops under the aorta and on the right under the branchiocephalic artery. The recurrent laryngeal nerves then turn superiorly running in tracheosephageal groove to enter into the larynx. Upon entering the larynx the recurrent laryngeal nerve proceeds to supply motor innervation to the laryngeal muscles in the following sequence: posterior cricoarytenoid, interarytenoid, lateral cricoarytenoid, thyroarytenoid. Only the interarytenoid muscle receives bilateral innervation.

The four main laryngeal nerves are seen to contribute to a complicated plexus. In addition, some axons from the internal SLN can be seen terminating among muscle fibers. There is evidence that some axons travel downward from the interarytenoid muscle to innervate the PCA but this is not a constant feature.

Anatomy of glottic region

The glottis consists of two portions; the intermembranous portion or the anterior glottis and the intercartilagenous portion, or the posterior glottis. The anterior glottis can be regarded as the phonatory glottis whereas the posterior glottis is considered the respiratory glottis. The vocal fold is defined as the fold like structure that lies between the anterior commisure and vocal process of arytenoids.[4]

Histological structure of vocal cord (Fig 7)

Vocal cord is made of mucosa and muscle. The mucosa in turn, consists of epithelium and lamina propria. Around the vocal fold edge, the epithelium is stratified squamous cell epithelium. The lamina propria can be divided into three layers. The superficial layer of lamina propria mainly consists of amorphous substance and it is loose and pliable. Elastic and collagenous fibers as well as fibroblast are sparse. This layer is called the Reinke's space. It is this layer which vibrates during phonation. If it becomes stiffened with pathologies such as inflammation, scar or tumor, its vibration will be disturbed. This results in voice problems. The intermediate layer consists primarily of elastic fibers, whereas the deep layer consists chiefly of collagenous fibers. The structures that consists of intermediate and deep layer of the lamina propria is called the vocal ligament. The vocalis muscle forms the main body of vocal cord.[4]

The basement membrane zone:(BMZ) (Fig 8)

This is an area between the epithelium and the superficial layer of the superficial layer of lamina propria. The basal cells of epidermis is attached by the attachment plaques (AP) to the sub-basal dense plate (DP) to the anchoring filaments(AFL) through the lamina densa of the BMZ to the anchoring fibers to the superficial layer of the lamina propria. Many of the structures are composed of one or more proteins. One such protein, epidermolysis bullosa acquisita (EBA)

is involved in the actual attachments of the epithelium to the underlying tissue.

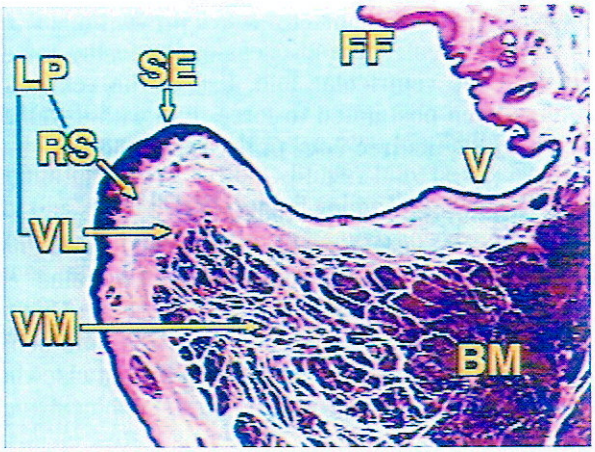

Fig 7 vocal cord cross sectional study. (SE- squamous epithelium, LP- lamina propria, RS- Reinke's space, VL- vocal ligament, VM- vocalis muscle, BM- body of thyroarytenoid muscle, V- ventricle, FF- false cord)

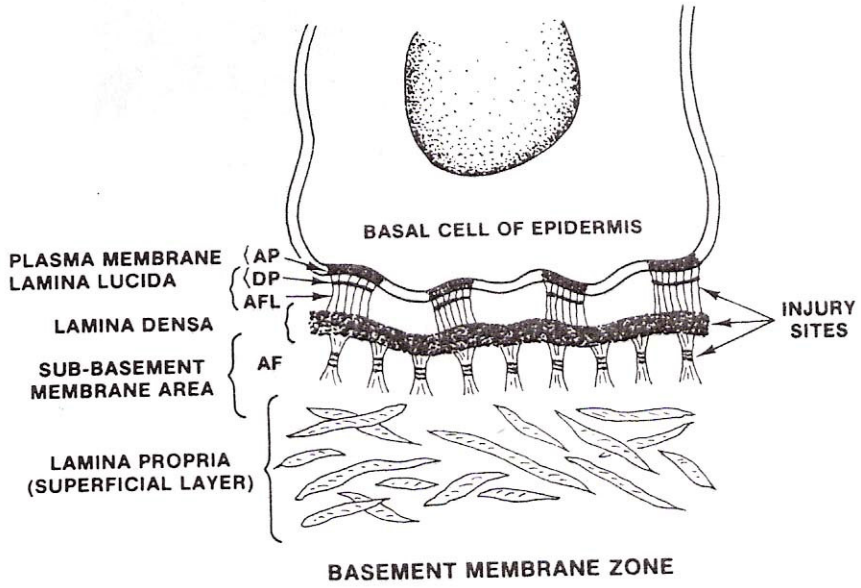

Fig 8 Basement membrane zone (AP- attachment plaques, DP- dense plates, AFL- anchoring filaments, AF- anchoring fibers)

The lamina densa area contains proteins that add strength to the BMZ. Type IV collagen is also found in the lamina densa region.

The BMZ is very susceptible to injury due to vibration and shearing forces. The fibers that anchor the BMZ loop from the lamina densa into the superficial layer of the lamina propria and then back to the lamina densa. Type III collagen fibers also appear to pass through these loops creating an arrangement that resembles a chain link fence.

Disease and trauma may damage these fragile connection links between the epithelium and the BMZ. It is conjectured that some aberrations of or injury to the BMZ maybe the cause of nodules and benign lesions. Once laid down, it tends to stay and had been implicated in scar formation. It has been found in human vocal nodules. But neither fibronectin nor collagen type II is found in human polyps.[5]

Physiology of phonation:

The voice is an integral part of the unique human ability to communicate by speech. The larynx is the major source of sound used during speaking. Phonation is the generation of sound by vibration of vocal cords.

THEORIES OF PHONATION:[6]

It is based on three theories.

a) Aerodynamic or myoelastic theory: (Van den Berg - 1958) this theory postulates that vocal cords are subject to well established aerodynamic and physical forces. There is a building up of infraglottic air column,

and its pressure act on the vocal folds which are kept tensed by the tonic contraction of the laryngeal muscles. This increased infraglottic pressure forces the vocal cords apart and it is set in vibration, once again the pressure falls, vocal cords recoil following which the subglottic pressure raises. The mode and frequency of vibration is dependent on properties of the cord and interplay of the intrinsic muscles of the larynx.

b) Neuromuscular or clonic theory (Husson): This is not accepted now. This states that each new vibratory cycles are initiated by nerve impulses transmitted from brain to the vocalis muscle by way of the vagus nerve. This means that the frequency of vocal cord vibration is dependent on rate of impulses delivered. There was very little conclusive evidence to support this theory.

c) Cavity tone or transient theory (Wills) this states that larynx functions simply to supply puffs of air that might excite the supraglottal resonating cavity. This explains sound production based on the resonation chambers alone.

<u>Body cover complex.</u>

The crucial event essential for voice production is vibration of the vocal cords based on the concept of cover body complex. The five histological layers are reclassified into three.

The cover: consisting of epithelium and the superficial lamina propria.

The transition: consist of intermediate and the deep layer of lamina propria

The body: consists of the vocalis muscle.

The degree of coupling between the epithelium and lamina varies, being very small in low frequency speech and may vary a great in falsetto voice.[7]

MECHANISM OF PHONATION:

Phonation requires co-ordinated interaction of the mouth pharynx, larynx diaphragm, and abdominal and neck muscles.

Normal phonation requires five conditions[8]:

1) Adequate breath support
2) Approximation of vocal cords
3) Favorable vibrating properties
4) Favorable vocal cord shape
5) Control of length and tension.

The upward movement of diaphragm pushes air from the lungs through the vocal folds, producing a train of air pulses. This pulse train is shaped by the resonances of the vocal tract. Basic resonances called vocal formants, can be changed by the action of the articulators to produce distinguishable voice sounds, like vowels sounds[9]

Phonatory physiology:

Glottal tone initiation[9]:

The process of phonation begins with inhalation of air. The vocal folds are approximated in the midline or near the midline (phonatory postion)and the glottic

space is obliterated. The subglottic pressure builds up to about 7cm of water, for conversational speech. The subglottic pressure then pushes the vocal cord progressively apart from the bottom up until a space develops. Bernoulli's effect of air flow along with the elastic forces of the cords begin to close the glottis almost immediately even while the upper edges are still separating. The upper portion of vocal cords has strong elastic properties which make the vocal cords to snap back to the midline completing the glottic cycle. Subglottic pressure then builds up again and events are repeated.

Bernoulli's effect is an important aerodynamic event responsible for closing the vocal cords. Bernoulli's law states that the sum of the static pressures at the kinetic pressures in a gas system is always equal to a constant. In the larynx, the vocal cords cause a partial obstruction of airflow. The molecules travelling along the sides of the trachea, when meeting the vocal cords, must travel a greater distance to meet the molecules in the centre of trachea. The molecules along the surface of vocal folds must increase their velocity and kinetic pressure. Thus the static pressure on the surface of the vocal folds will be decreased. Thus the pliable and movable vocal folds will begin to move towards the centre of the trachea because of this pressure differential. Eventually, the two cords will meet in the midline, and airflow will cease.

When the cords close there is sudden decrease of airflow and when it opens there is a momentary delay in starting the flow of air due to the inertia. This gives the characteristic shape of the airflow pulse through the glottis where

the rising airflow phase is slower than the opening of the vocal folds. Intra glottic pressure is solely dependent on particle velocity.

It is necessary to properly tense and elongate the vocal cords prior to actually producing sounds, which is regulated by the laryngeal muscles. It is also important that in the myoelastic – aerodynalmic mechanism of phonation the vocal cords emit pulses of air and also there is a vertical phase difference; that is, the lower portion of vocal cord begins to open and close before the upper thus producing a rippling displacement of the vocal cord cover. Thus mucosal wave can be examined by stroboscopic light.

The vocal cord length, mass and tension determines the fundamental frequency. Fundamental frequency which corresponds to pitch can be altered by changing the air pressure or the mechanical properties of the vocal cord. Contraction of cricothyroid muscle along with the thyroarytenoid muscle increases the length and tension of the vocal cords, resulting in raising the pitch. In the lower vocal range, contraction of thyroarytenoid alone results in lower pitch because it decreases the tension in the vocal cover. Vocal frequency decrease as the mass of the cord increases. The vocal intensity corresponds to loudness. The sound generated by vibration of the vocal cords is then modulated by the resonating chambers. Resonance is controlled by altering the shape and volume of pharynx, by raising and lowering the larynx, by moving tongue or jaw position, or by the nasopharynx and nose. Voice training for singing, acting and public speaking concentrates heavily on refining and maximizing resonance. The goal is

to produce the most loudest and pleasing sound with minimal strain or pressure on the larynx.

Common voice Complaints

Hoarseness means change in voice. This term is used by patients to describe changes in their voice quality.

Dysphonia means abnormal voice, but the degree of dysphonia does not correlate with any particular specific cause. It may present with mild, moderate, or severe dysphonia.

The symptoms of dysphonia may be further subclassified, as Diplophonia (double-tone), Dysresonance (change in the resonance of the voice). Voice breaks exemplify pitch-specific dysphonias. Odynophonia implies uncomfortable or painful speaking. Vocal fatigue is a common symptom among voice disorder patients and implies the development of symptoms (dysphonia or odynophonia) sometime after the initiation of vocalization[10].

Aphonia is used to describe the loss of voice; such patients may still be able to communicate in a quiet environment using the airstream for articulation, but the glottis does not participate in phonation. The sound of aphonia, then, is characteristically no voice or extreme breathiness.

Classification of dysphonias:

A) Functional dysphonias:[11]

1. Muscle tension dysphonia - Type 1,2,3,4.

2. Psychogenic dysphonia (Hysterical aphonia)- Conversion dysphonia & Falsetto.
3. Habituated Hoarseness- Plica ventricularis (idiopathic), post viral, post operative.
4. The vocal abuse syndromes-Tension fatigue syndrome (MID), Bogart Bacall syndrome, vocal cord nodules,polypoid degeneration (Reinkes edema),vocal process ulcer or granulomas,
5. Post operative dysphonia
6. Relapsing aphonia.

B) ORGANIC VOICE DISORDERS:

Epithelium- leukoplakia, hyperkeratosis, carcinoma in situ, carcinoma

Lamina propria lesions- Reinke's edema(diffuse), nodules polyp, scar, reactive lesion, subepithelial cyst, deep cyst, vascular-varices, ectasias.

Arytenoid- vocal fold granuloma, infection

Others- laryngeal or glottal web, stenosis.

C) MOVEMENT DISORDERS OF THE LARYNX (Neurologic)

1. Vocal cord paralysis and paresis
2. Central: cerebrovascular accident, Gullian Barre syndrome, head injury, multiple sclerosis, neural turnors .

. 3. Peripheral: tumours (glomus, thyroid, bronchogenic, esophageal,neural): surgery (thyroid, cardiovascular or thoracic or esophagcal)

4. Neuromuscular- Myasthenia gravis, Parkinsonism, spastic dysphonia, vocal tremor.

D) SYSTEMIC: Endocrine (hypothyroidism, virilization), Rheumatoid arthritis, systemic lupus erythematosis, sarcoidosis, Sjogren's syndrome, Diabetes mellitus, amyloidosis.

E) CHRONIC IRRITATION: Gastro esophageal reflux disorder, smoke, chronic cough (leading to edema, nodules, contact ulcers, chronic laryngitis)

F) TRAUMA: Extemallaryngeal trauma

G) IDIOPATHIC: Spasmodic dysphonia

H) AGED: Presbylaryngis

Benign vocal cord lesions have an effect on phonatory physiology. Thus they cause dysphonia.

Evaluation

Evaluation of the voice includes examination of the laryngeal structures by stroboscopy and voice spectrography voice analysis. Additionally, administration of the Voice Handicap Index (VHI) provides an assessment of the level of handicap experienced by the patient with the voice disorder.

Stroboscopy (Fig 9)

Stroboscopy is a technique for direct observation of laryngeal vibration. Stroboscopic examination of larynx was first performed by Oertel in 1878.

The vocal folds vibrate at a frequency of approximately 250 times per second while phonating at middle "c ". Naturally, the human eye cannot discern

Fig 9 Stroboscope and capture device.

necessary detail during rapid motion. Talbot's law takes into account the physical reality that the images on the human retina linger for 0.2 seconds after exposure. Therefore the sequential images produced at intervals of less than 0.2 seconds produce the illusion of a continuous image. The stroboscope actually illuminates different points on successive waves of vibratory cycles, each of which is retained on the retina for 0.2 seconds. The light source of the machine emits intermittent flashes at a rate that can be set by the examiner or controlled by fundamental frequency of the voice. When vocal cord vibration and the stroboscopic light are synchronized the vocal cord will appear still rather than moving in slow motion. The frequency of the examinee's sustained voice is picked up by the microphone and this triggers the light source. When the flashes are emitted at the same frequency as that of the vocal cord vibration, that is, at an identical phase point in successive vibratory cycles, a sharp and clear image of the vocal cord is observed. When the frequency of the flashes is slightly less or greater than the vocal vibration, there is a delay in the portion of the vibrating cycle illuminated and the illusion of slow motion is obtained.

The various parameters studied by stroboscope include symmetry, amplitude, periodicity, completeness of vibratory closure, and the mucosal wave. It is possible to observe both transverse opening and closing of the folds and the vertical sliding motion (mucosal wave) of the mucosal cover over the body. A dynamic picture and detailed vibratory behavior of vocal cords is also observed in this procedure.

The parameters studied by stroboscopy are defined below.

1) Fundamental frequency:

The rate at which the vocal cord vibrates in one single second is called fundamental frequency. The fundamental frequency varies from person to person. It is lower in males than in females.

2) Periodicity:

Periodicity refers to the regularity of successive vocal movements. Regular periodicity depends on balanced control of expiratory force and the mechanical characteristics of the vocal folds. Irregular periodic movements may be caused by either an inability to maintain a steady expiration stream of air or/ and an inability to sustain steady laryngeal muscle contraction. Periodicity may also be affected by a difference in the mass or stiffness of one of the vocal cords.

3) Amplitude.

Amplitude refers to the lateral excursion of the vocal folds during their displacement away from the midline. Generally, amplitude is approximately one third of the total width of vocal folds. Small amplitude of vibration is associated with short vibrating segments of vocal folds; increased stiffness or increased mass of the vocal cords. Amplitude is increased by increasing subglottic pressure, such as which occurs with loud phonation. Amplitude is not generally affected by masses like small cysts and early vocal nodules.

4) Mucosal wave:

The pattern of light traveling from medial to lateral along the superior surface of the vocal cord during vibration under illumination is called mucosal

wave. It is diminished by scarring, dryness, mucosal stiffness epithelial hyperplasia and masses involving the vocal cords. Falsetto phonation also affects mucosal wave. Loud phonation may increase the mucosal wave. It can be altered by hypo or hyper functional voice technique.

5) Glottic closure:

Normal subjects demonstrate complete closure of the membranous portion of the vocal cord during a vibratory cycle. The posterior cartilaginous glottis may remain open in some normal patients. Failure of closure may be due to local pathology or due to neural paralysis. Glottal closure may be complete or incomplete, consistent or intermittent, and may involve a posterior chink, a specific or a small portion of the vocal fold as in certain vocal cord paralysis. If there is any portion of cord which does not vibrate, that should be specified. These portions are specified as adynamic segments. Hypo dynamic segments may also occur temporarily, as seen sometime in acute vocal cord hemorrhage with submucous hematoma.

Phonetic and linguistic systems:

Speech is the major source of communication in humans. Speech is only acceptable and intelligible and regarded by the user as natural when it is produced and received according to a certain pattern. It has evolved as a very practical and robust method of communication. Information processing attempts to conceptualize the various memory structures and processing stages presumed to operate between the stimulus onset and individual response.

The vocal tract provides an example of a vibrating system which has a number of resonators with different natural frequencies, and different degrees of damping. Vocal tract resonances are called 'formants'.

Controlled change, with time, of the parameters of the system is an essential aspect of the patterned structure of speech production which is neither simple in regard to its representation in terms of resonant components, nor in respect of its stability with time. The voiced sounds of speech have an input to the vocal tract, derived from the quasi-regular pulsatile pressure changes, which are the result of interruption of tracheal air stream by the vocal cords. A 'spectrogram' is a time frequency graph which shows how the changing shape of the speaker's vocal tract has altered its resonant structure so that it responds selectively in frequency to the acoustic energy output from the larynx.[12] This output is fed into a real time analyzer.

ACOUSTIC ANALYSIS (Fig 10)

Specific parameters of voice production which are analyzed in voice analysis are fundamental frequency, maximum phonation time, jitter, shimmer, noise to harmonic ratio and maximum phonation range.

1) Fundamental frequency:

This measure refers to the rate of vibration of vocal cord during the production of sustained vowels and while reading a passage. It is useful for comparing intra and inter subject pitch levels. It can vary depending upon the

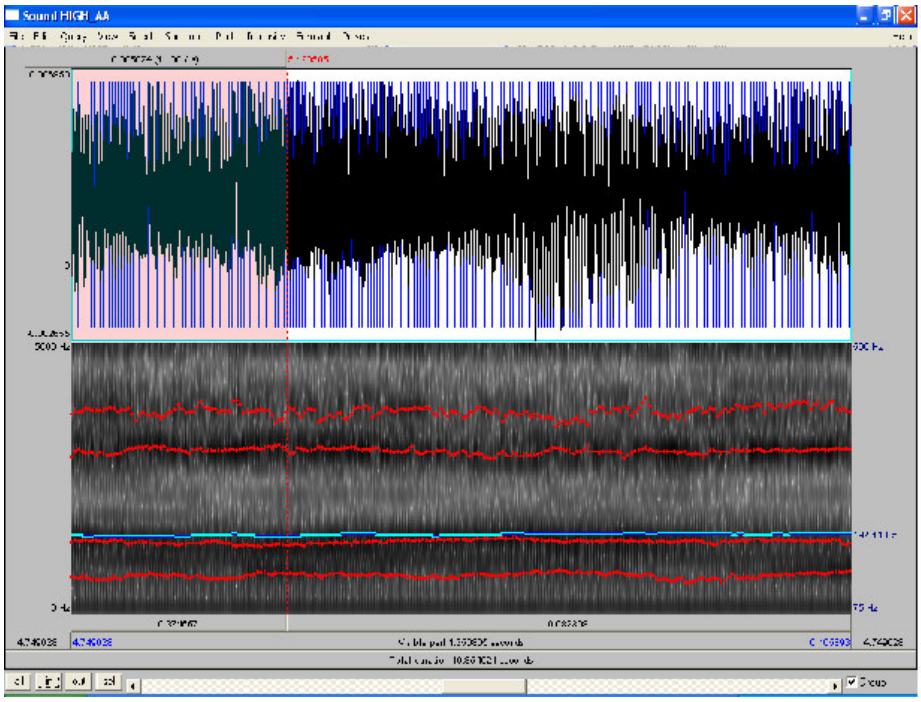

Fig 10 Spectorgram

type of speech material used. Variability is much less for sustained vowels than for reading passages. Fundamental frequency variability or lack thereof may be a physical measure that relates to the perception of voice monotone, a perceptual sign noted in some voice disorders.

2) Maximum phonation time:

Maximum phonation time refers to the maximum duration that a particular vowel sound can be sustained.

3) Jitter / Frequency perturbation:

Jitter is the measure of instability of the vocal cord during sustained phonation. Frequency perturbation or jitter refers to the variation of fundamental frequency present in all speakers to some degree and detected when the subject is attempting to produce a steady, sustained vowel. The frequency variations are the result of instability of the vocal folds during vibration. As such perturbation reflects the biomechanical characteristics of the vocal folds, as well as variations of neuromuscular control. Normal speakers have a small amount of frequency perturbations, which may vary according to age, sex and physical condition.

4) Shimmer / Amplitude perturbation:

During sustained vibration, the vocal cords exhibit slight variation of amplitude from one cycle to the next. This is called amplitude perturbation or “shimmer”. Normal speakers will present with a small amount of shimmer, which is dependent on the vowel used and the sex of person.

5) Maximum phonation range:

Maximum phonation range refers to the range of frequencies, from the lowest to highest that an individual can produce. The intensity of the tone is usually not controlled, and the person may be asked to sustain the tone for one full second. Placing further demands on the production of the sound may be expected to alter the magnitude of the range obtained.

6) Vocal intensity:

The intensity of phonation observed during speech is dependent on several factors. These are intensity produced at glottis, shape of vocal tract, the amount of lip opening and the distance of microphone from the lips of the subject. Physical and emotional factors also reflect the vocal intensity.

7) Harmonic to noise ratio.

Voice is composed of periodic and random noise (aperiodic waves). Noise is a sound and is not a harmonic of fundamental note. If the noise component of voice increases and replaces the harmonic structure, the quality of hoarseness is perceived, and this is measured as the harmonic to noise ratio.

VOICE HANDICAP INDEX:

Voice handicap index is a patient stated measure of the impairment of voice. It was developed to determine the outcome in patients with voice disorders, shifting the focus from the clinician's judgment to patient's perception of problem.

Measuring the severity of a voice disorder is difficult. Methods have ranged from subjective measures of severity of voice disorder including perceptual judgments to objective measurements of voice characteristics. These methods can yield valuable data. They do not provide insight into why patients with similar voce disorders experience differing levels of handicap and disability.

Disability and handicap have specific definitions. Disability is “a restriction or lack of ability manifested in the performance of daily tasks”. Handicap is “a social economic or environmental disadvantage resulting from an impairment or disability”. So a voice handicap might occur when a person changes jobs because he cannot give presentations as required in his present position due to vocal requirements.

Several types of questionnaires are developed to self evaluate voice disability. Llewellyn Thomas (1984) developed a linear analogue scale that was an attempt to quantify self assessment of voice quality in laryngeal cancer patients. Smith et al (1994) designed a questionnaire to elicit information from patients regarding the functional impact of voice disorders in various aspects of life, specifically on employment, symptoms, risk factors and family history. This was the first study to evaluate the impact of voice disorders on quality of life dimensions. The other questionnaires available are The Voice Symptom Scale (VoiSS) and Voice Handicap Index 10 (VHI10).

The VHI used in the present study is the one developed by Jacobson and Johnson in 1997. This consists of a set of questionnaire which has three parts that is functional, emotional and physical parts. Each part has thirty questions

and each has a value of one and the maximum disability is 120 and minimum for a normal person is below 10.[13]

Voice handicap index (VHI) is the most widely used questionnaire in many studies. The validation of VHI was done by Jacobson et al in 1997. Later comparisons were done by Wilson JA[14] et al with the voice symptom scale. In 2004 Rosen et al[15] compared VHI with VHI10 a condensed version of the same.

Benign vocal cord lesions: Pathogenesis, Pathology and Clinical features.

Benign vocal fold mass lesions are a broad spectrum of lesions, each of which has a different pathology. They include pathologies like vocal nodules, vocal polyps, vocal cysts and Reinke's edema. The pathogenesis of all the lesions is similar. Vocal abuse is the chief predisposing factor. Other associated factors include smoking, laryngopharyngeal reflux (LPR), environmental irritants, endocrine disorders like hypothyroidism and allergy. The manner in which these these factors produce these lesions include, microtrauma; Excessive force causes disruption of capillaries and changes in vascular microcirculation. Temporary ischemia results, leading to increased permeability and edema of the lamina propria. Organization of the hematoma followed by fibrosis occurs and a nodule results, Voice misuse causes changes in medial edge of the vocal cord. Direct compression occurs due to hammering effect of each vocal fold during phonation. [16] The junction of anterior one third and posterior two third is the place where there is maximum trauma. This is roughly the midpoint of membranous cord.

Microscopic pathology:

Often the Heamotoxylin and Eosin stains of nodules and polyps look alike. Vocal fold polyps have been attributed to vocal abuse that has resulted in a hemorrhagic event or increased vascular permeability. Nodules have also been attributed to vocal abuse that has caused a thickening of the epithelium or lamina propria.

There are two types of histological response to trauma of the vocal cord.

Type one:

This is due to lamina propria disruption, usually associated with severe basement membrane zone injury. This injury leads to an aggravated healing response marked by fibronectin deposition. The thickness of the collagen type IV band confirms the extent and aggravation of basement membrane zone injury sustained. The injury, if repetitive, leads to aberrant healing and a fibroblastic response involving increased fibronectin deposition. Its presence in excess probably does not contribute to efficient tissue vibration.

Type two:

Pathologic finding shows few structural proteins such as collagen or elastin, and little or no fibronectin. Clinically, this absence of the structural glycoproteins and fibrous proteins would lead to a vocal fold with excessive propensity for deformability. The injury often seems to be confined to the lamina propria only and apparently does not consist fibroblastic response of tissue repair. This second type of patholoogic response is seen more often in Reinkes edema and some polyps.[17]

The various benign vocal cord lesions are considered individually.

Vocal cord nodule (Table 1, Fig 11)

This is the most common vocal cord lesion in adults and children. It is commonly seen in teachers, preachers, and children, all of whom speak in high pitched voice. It is often referred as singer's nodules and screamer's nodules in children. Hoarseness is the common presentation. In the case series of Kleinsassser[18] the majority of the patients were female and aged from 20 to 40 years. It occurs at the free edge of the vocal cord at the junction of anterior one third and posterior two third. Vocal nodules are seen bilaterally. They are white, small, sessile, and often symmetric. Occasionally long standing polyps with contralateral contact changes will produce a similar picture.

The initial event in the formation of a vocal cord nodule is edema and vasodilatation. This may progress to hyalinization of the nodule and epithelial hyperplasia. Histological examination shows, hyperkeratotic epithelium with parakeratosis. The subepithelial layer is infiltrated by irregular collagen fibers and fibroblasts.

Stroboscopy shows pronounced vibration of the anterior segment of vocal cord with asymmetry and aperiodicity. Voice analysis: shows breathiness of voice with reduced loudness and with increased jitter, shimmer and harmonic to noise ratio.[19]

Fig 11 Vocal cord nodule

Fig 12 Vocal cord cyst

Vocal cord cysts (Table I, Fig 12)

Vocal cord cysts mainly affect the adult population. Only 6% of patients in one series were less than 20 years of age. There are two types of cysts, mucous retentions cysts and epidermoid cysts. Vocal cysts are mainly unilocular and unilateral. Multilocular and bilateral, multiple vocal cord cysts of various sizes may also be seen.[20] Small sized vocal cord cysts are difficult to differentiate from vocal nodules.

Mucous retention cysts are formed by blockage of mucous glands found on the under surface of the vocal cord. Histologically they are lined by cuboidal or coloumnar epithelium resembling respiratory epithelium. Epidermoid cysts are formed either by the ingrowth of the epithelium into the cord, by microtrauma or as a congenital anomaly. Histologically, the cavity is lined by keratinizing squamous epithelium and contains desquamated epithelium and cholesterol crystals[21] . The content of the cyst is dependent on the epithelium. In cases of mucous retention cysts, the content may be watery thin and mucoid. In epidermoid cysts it is inspissated debris.

Stroboscopy of laryngeal cysts show hyperkinetic pattern of mucosal wave in regions other than the area of cyst. Usually cysts shows a normal or reduced mucosal wave. Voice analysis shows the same picture as vocal nodule.

Vocal cord polyp: (Table I, Fig 13)

These lesions arise only from the membranous part of the vocal cord, usually close to the anterior commisure. Vocal polyps develop when there is an

initial high subglottic pressure followed by abrupt reduction. This causes trauma to the basement membrane zone, leading to hyperemia and edema. If accumulation of edema is concentrated at a particular point that part is ballooned and polyp is formed.[22] Phonotrauma with use of anti platelet drugs or anticoagulants can predispose to hemorrhagic polyps. Majority of the patients with polyps are males (70%) and smokers (80%)

Histopathologically there are three types of polyps namely; gelatinous, telangiectatic and mixed type. Gelatinous polyps have a very loose edematous stroma and sparse collagen, few fibrocytes, histiocytes and mast cells. Telangiectatic polyps have homogenous eosinophillic deposits and fibrin collections in the stroma. Labrynthine type of vascular channels are seen in the stroma. The mixed type of polyp has features of both the gelatinous and telangiectatic type. These are the most common type of polyp seen.

Stroboscopy: shows adynamic segments, with aperiodicity and asymmetry.

Voice analysis will shows breathiness of voice with reduced loudness and with increased jitter, shimmer and harmonic to noise ratio.

Reinke's edema: (Table I, Fig 14)

This entity is also known as polypoidal degeneration, chronic polypoidal corditis, chronic edematous hypertrophy or chronic hypertrophic laryngitis[19]. Smoking is the major etiological factor identified. Fritzel in his retrospective study (1986) found that more than 95% of affected patients were smokers. In a study by Kleinsasser 98% were smokers[20]. Other causative factors include LPR and

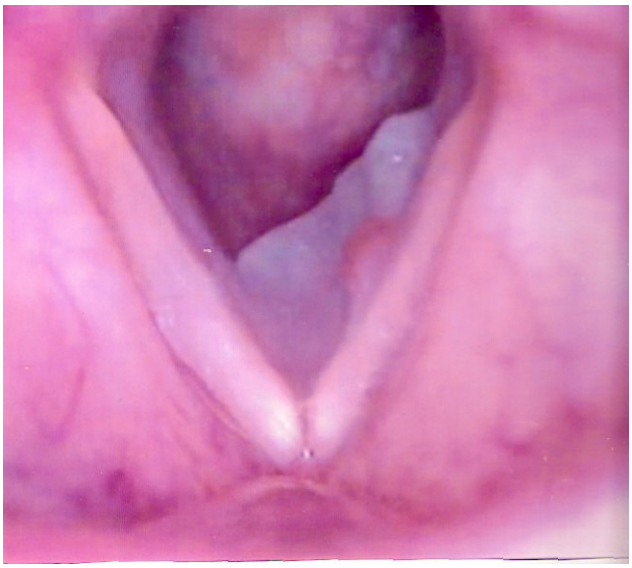

Fig 13 Vocal cord polyp

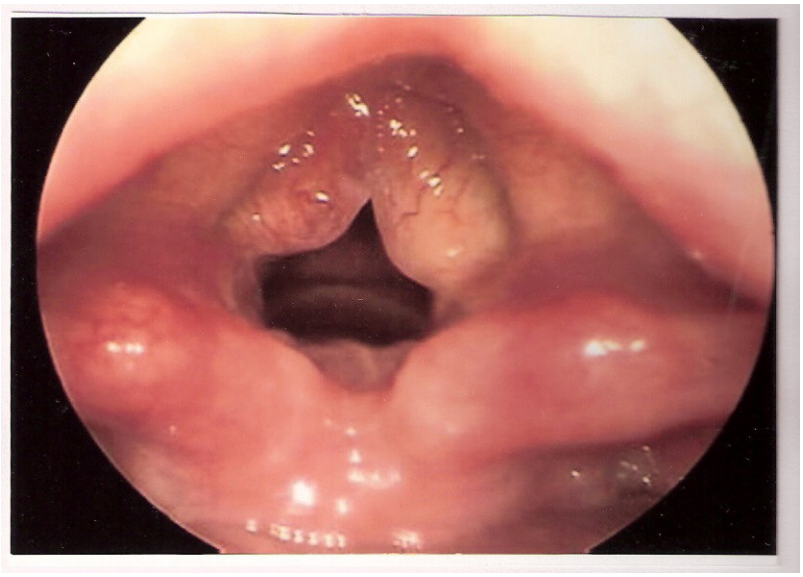

Fig 14 Reinke's edema

voice abuse. An abnormal increase of the glottic pressure with caustic exposure leads to increased vascular permeability and edema of the vocal cord. The association between thyroid dysfunction and Reinke's edema has also been shown. The accumulation of fluid in the superficial lamina propria.

Histologically Reinke's edema is divided into pale and livid types.[23] In the pale type, a limited, fusiform glazed swelling is noted. The epithelium is thin and collection of clear watery fluid is visible. Stromal cells with numerous intracytoplasmic granules are seen. In the livid type, the colour changes to yellow gray and fluid thickens to glue like consistency. Additionally multiple dilated and irregular vessels are present.

Hoarseness is the presenting symptom. Stroboscopy shows that the body of the cord is not affected. Glottic closure is usually complete and the cord shows a fusiform, ballooned out appearance. Stroboscopy shows loss of mucosal wave. Loss of symmetry is variable and the closure can be complete. Voice analysis shows low fundamental frequency and high jitter and shimmer. Harmonic to noise ratio is also increased.

Table I

Comparative characteristics of studied benign vocal cord lesions:

	Vocal nodule	Vocal cyst	Vocal polyp	Reinke's edema
Age Sex	Female Adults and children	Equal Adults	Men Adults	M:F 2:1 Adults
Profession	Professional voice users	-	Voice abuse	-
Predisposing factors	Untrained voice usage	Trauma to vocal cord	Smoking Untrained voice users	Smoking Moderate voice stress
Flexible nasopharyngolaryngoscopic picture	Hour glass closure	Smooth swelling	Sessile or pedenculated polypoidal or hemorrhagic mass	Diffuse polypoidal edema / Fusiform enlargment
Stroboscopic picutre	Aperiodic Asymmetric Reduced wave	Aperiodic Reduced/ normal wave	Adynamic segments Aperiodicity Asymmetry	Absent mucosal wave Asymmetry
Voice analysis	Reduced loudness Increased jitter and shimmer	Reduced loudness Increased jitter and shimmer	Reduced loudness Increased jitter, shimmer and harmonic to noise ratio	Increased jitter, shimmer and harmonic to noise ratio

MATERIALS AND METHODS

I MATERIALS

1. Study design:

A prospective cohort study of 30 patients with benign vocal cord lesions, were included in the study.

2 Setting:

Department of ENT and Head and Neck Surgery, Christian Medical College and Hospital, a 2000 bedded , multispeciality teaching institution .

3 Patients

Inclusion criteria

- Patients with benign looking vocal cord lesion
- Age above 12 years
- Freely mobile vocal cords on fiberoptic endoscopy / indirect laryngoscopic examination

Exclusion criteria

- Patient with malignant looking lesion on endoscopy.
- Patient in respiratory distress
- Patient with ischemic heart disease

- Inability of patients to return for follow up at six weeks

II Methodology

Patients with a clinical diagnosis of a benign vocal cord mass lesion such as a vocal polyp, vocal nodule etc were enrolled in the study. Each patient preoperatively underwent three procedures namely, fiberoptic larnyngoscopy, stroboscopy and voice analysis after procuring the consent from them.

Fiberoptic laryngoscopy:

Fiberoptic laryngoscopy is a useful way of demonstrating laryngeal pathology. This provides an excellent view of the larynx, it is particularly suited for patients who are unco-operative for indirect laryngoscopy.

Procedure:

The patient sat facing the standing examiner. Each patient was sprayed with a mixture of 4% or 10% lignocane and decongestant (1% oxymethazoline) in the nose and oropharyngeal mucosa. A 4 mm flexible fiberoptic nasopharngolarngoscope was passed per nasally under direct control and vision. The visualized areas were the floor of nose, nasopharynx, oropharynx and the larynx. The larynx was examined in detailed fashion to note the size, shape of vocal cord lesion, presence of hemorrhage and whether the lesion was pedunculated or sessile lesion. The contralateral vocal cord was assessed at the site of approximation. At the same time cordal mobility was also assessed.

Stroboscopy:

Stroboscopy is a procedure which allows routine slow motion examination using a laryngeal stroboscope, a 90 degree Hopkins telescope. The procedure was performed after nasopharyngolaryngoscopy.

The procedure was explained to the patient before starting with particular reference to the need to keep the mouth open and avoid swallowing during the test. Local anesthetic was provided to the larynx with 10% lignocane topical spray. After a few minutes (having given time for the anesthetic to act) the patient was asked to open the mouth wide and protrude the tongue. The tongue was held by the examiner with a gauze piece, simultaneously supporting the upper jaw. The telescope was introduced into the oropharynx to visualize the glottis after using a antifogging solution. The patient was asked to phonate with long “eee” to see the cords in motion. While the patient was phonating the stroboscopy pedal was pressed so as to produce pulsed light in accordance to the patient’s fundamental frequency.

The patient underwent for stroboscopy which was done by using a Karl Storz stroboscope.

The output picture and sound was captured into a computer using a capture card without compression and analyzed later.

The stroboscopy picture was analyzed to note:

1. Symmetry (symmetry of movement and approximation of vocal cords)
2. Mucosal wave (pattern of light traveling on the vocal cord)

3. Glottic closure (completeness of glottic closure)

Voice handicap index:

A number of voice handicap questionnaire have been designed for assessment of patients with voice disorders. In this study the questionnaire developed by "Jacobson et al[13]" was used. All patients were administered the questionnaire and a measure called the voice handicap index was calculated. The measurer refers to the total sum obtained (minimum of '0' and maximum of '120') when the voice handicap score is administered.

Voice analysis

The next step in evaluation was voice analysis. Each patient was taken to a sound proof room to record voice using a low impedance commercial microphone and asked to phonate in low and comfortable voices. Each of these vowel sounds were voiced for at least of 15 to 20 seconds for low and comfortable intensity. Speech is recorded in intensity comfortable for the patient. Only a good quality continuous signal was selected and used for analysis. Speech sound was recorded by asking the patient to count numbers slowly and clearly. The recorded voices are stored in computer for analysis.

Voice analysis was performed on PRAAT software version 4.3.22. "PRAAT" is an open source freeware developed specifically keeping in mind scientific analysis of the sound signals recorded in "wav" format. This software is freely available in internet (freeware). This is an opens source code; which means that the program can be altered to fit to individual necessity.

The parameters that were observed on voice analysis were

1. Fundamental frequency (vibrating frequency of the vocal cord)
2. Standard deviation of fundamental frequency.
3. Jitter (variation of fundamental frequency)
4. Shimmer (variation of amplitude from one cycle to cycle)
5. Harmonics to noise ratio (amount of noise in voice)

Surgery

After the complete preoperative workup, all patients underwent micro laryngeal surgery using a suspension laryngoscope under general anesthesia. The surgeon was not the same for all the patients. At surgery, the lesions were completely excised to the satisfaction of the surgeon and an independent observer.

Post operatively, patients were advised voice rest for a period of two weeks. Advice regarding the usage of voice and the do's and don'ts following surgery were given. Contact numbers of all patients were noted.

Post operative review:

All the operated patients were asked to come for review at a date 6 weeks following surgery. The tests conducted on review were

1. Stroboscopy
2. Voice analysis

3. Voice handicap index questionnaire

The methodology used for each patient was similar to that used preoperatively.

4 Statistical methods:

Sample size was calculated using the formula given below.

Calculation of sample size:

Sample size was calculated as 42 as per the formula

$$n = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2}{\Delta^2} + \frac{(Z_{1-\alpha/2})^2}{2}$$

$\Delta = H1-H2/\sigma$ $\sigma = \sigma_1 + \sigma_2/2$

The study used to calculate sample size was that by ' Woo P et al'[8] , in which the, mean and standard deviation were

H1= pre test mean (0.28)

H2= post test mean(0.38)

σ_1 = pre test SD(0.13) σ_2 = post test SD(0.32)

$Z_{1-\alpha/2}$ = 5% α error (1.96)

$Z_{1-\beta}$ = 80% power (0.84)

Descriptive statistics were used to describe the frequency distribution of various patient factors. Pre and post measurements on different parameters was compared using McNemar's test and paired t test. McNemar's test was used to compare paired categorical / discrete measurements. 'Rather paired t test' was used to compare continuous measurements. All statistical analysis was done using SPSS (statistical package for the social scientist version 11.0) on an IBM compatible PC.

Results

Demographic characteristics:

Age distribution:

In the group of 30 patients the mean age was 36.53. The youngest subject was 18 years and oldest 62 years old.

Sex distribution:

A total of 30 patients were enrolled in this study. A male preponderance (n=21) was seen.

Geographic distribution: (Fig 15)

The majority of my patients came from West Bengal (66.7%), while the local population consisted of 9 (30%). One patient (3.3%) came from Assam.

Duration of complaint:

Among the 30 patients; a mean duration was 11.80 months. The range of duration of complaint was 1 to 45 months.

Associated habits and history:

Voice demand and voice abuse:

In the group of 30 patients; there were no professional voice (grade I) users like singer or preacher. On categorizing them according to the voice demands, there were professional voice users (grade II) (n=10) non professional

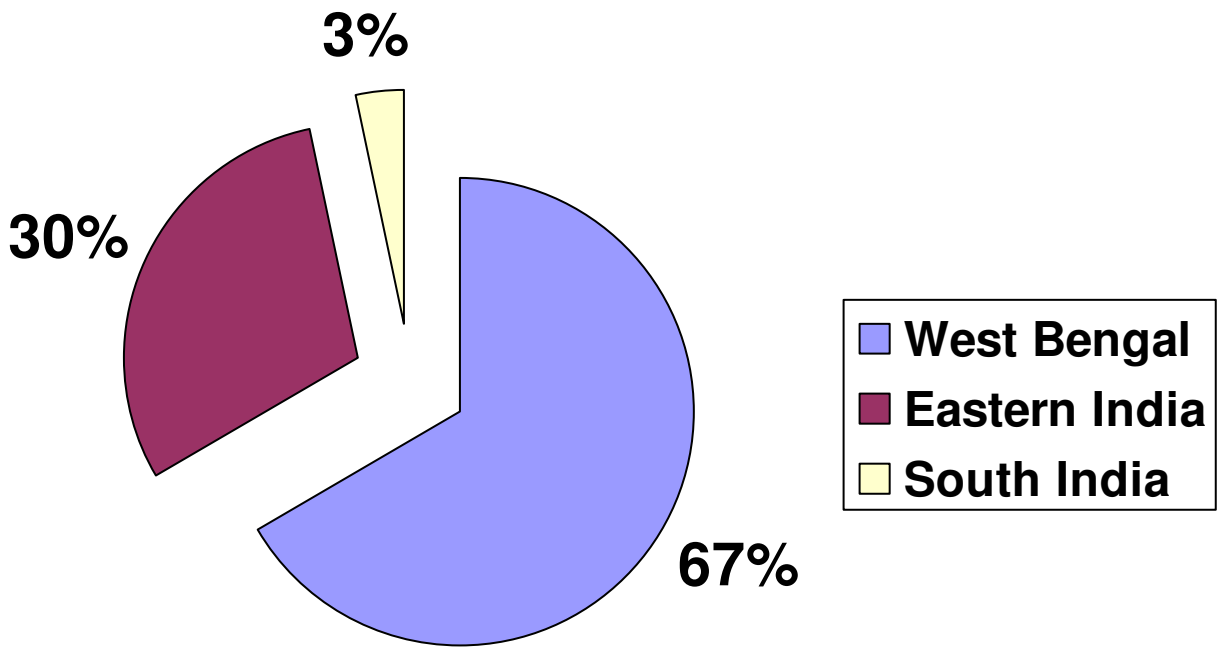

Fig 15 Geographic distribution of patients.

voice users (grade III) (n=4) and non professional non voice users (grade IV) (n=16).

Voice abuse is one of the known etiological factors for benign vocal cord lesions. We found 20 patients with history of voice abuse.

Smoking: (Fig 16)

Among the 30 patients 22 (73.3%) were non smokers and 8 (26.7%) were smokers. All the smokers were males.

Laryngo pharyngeal reflux (LPR): (Fig 17)

We had only 2 patients with typical history of LPR.

Muscle tension dysphonia (MTD) (Fig 17)

Among the 30 patients 23.3% (n=7) were found to have muscle tension dysphonia.

Stroboscopic parameters:

Pre operative analysis (Table 2)

Symmetry:

Asymmetry was was a hallmark in almost all patients (93.3%) with vocal cord lesions.

Mucosal wave:

The mucosal waves of the right and left cord were analyzed separately.

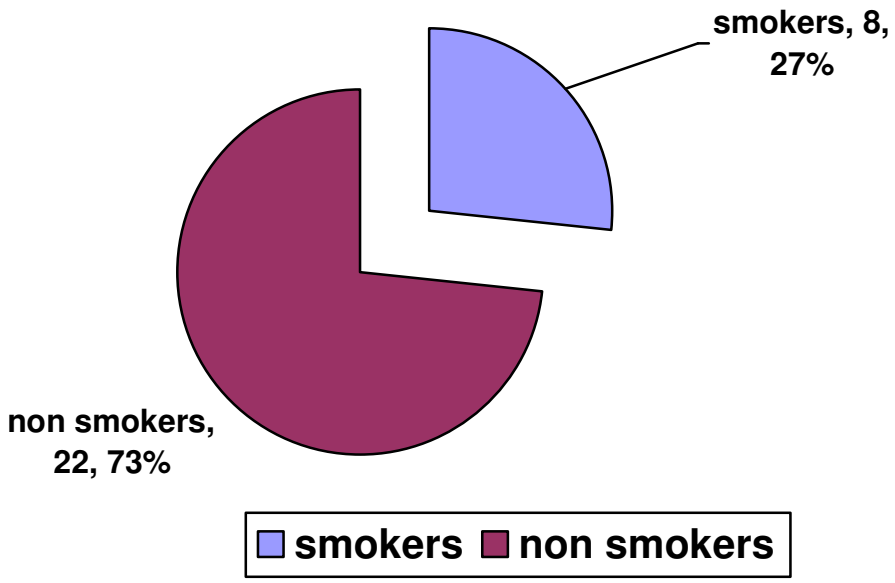

Fig 16. Prevalence smoking in patients

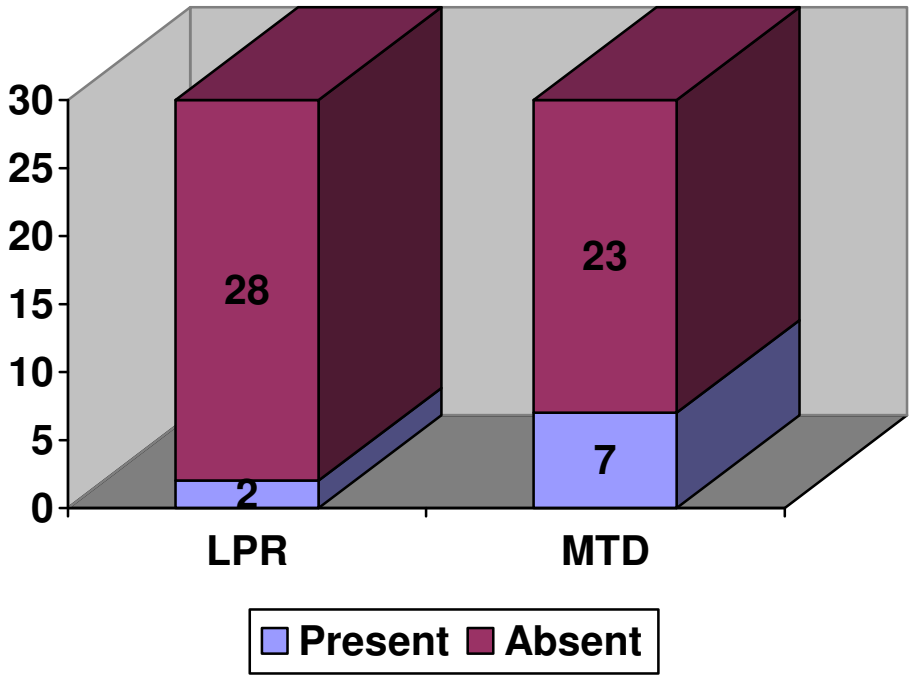

Fig 17 Prevalence of associated findings

Mucosal wave (right)

The mucosal wave was absent in less than half (40%) the patients on the right vocal cord. One patient (3.3%) had scarring of right vocal cord and resultant absent mucosal wave.

Mucosal wave (left)

A total of nine patients (30%) had absent mucosal wave. Fewer patients had absent mucosal wave on the left than the right. However this is because more patients had lesions located on the right vocal cord.

Glottal closure:

All the patients examined were found to have incomplete closure of the glottal chink.

Table 2

Pre operative stroboscopic analysis (n=30)

	Present	Absent
Symmetry	2	28
Mucosal wave (right)	17	12
Mucosal wave (left)	21	9
Glottic closure	0	30

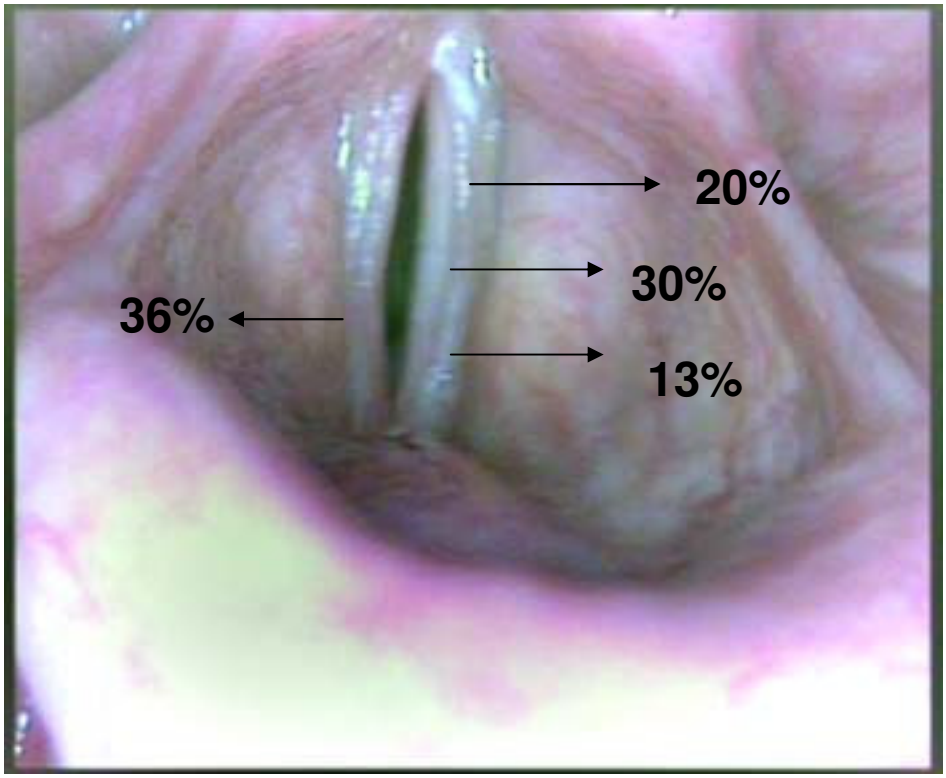

Fig 18 Site of lesion

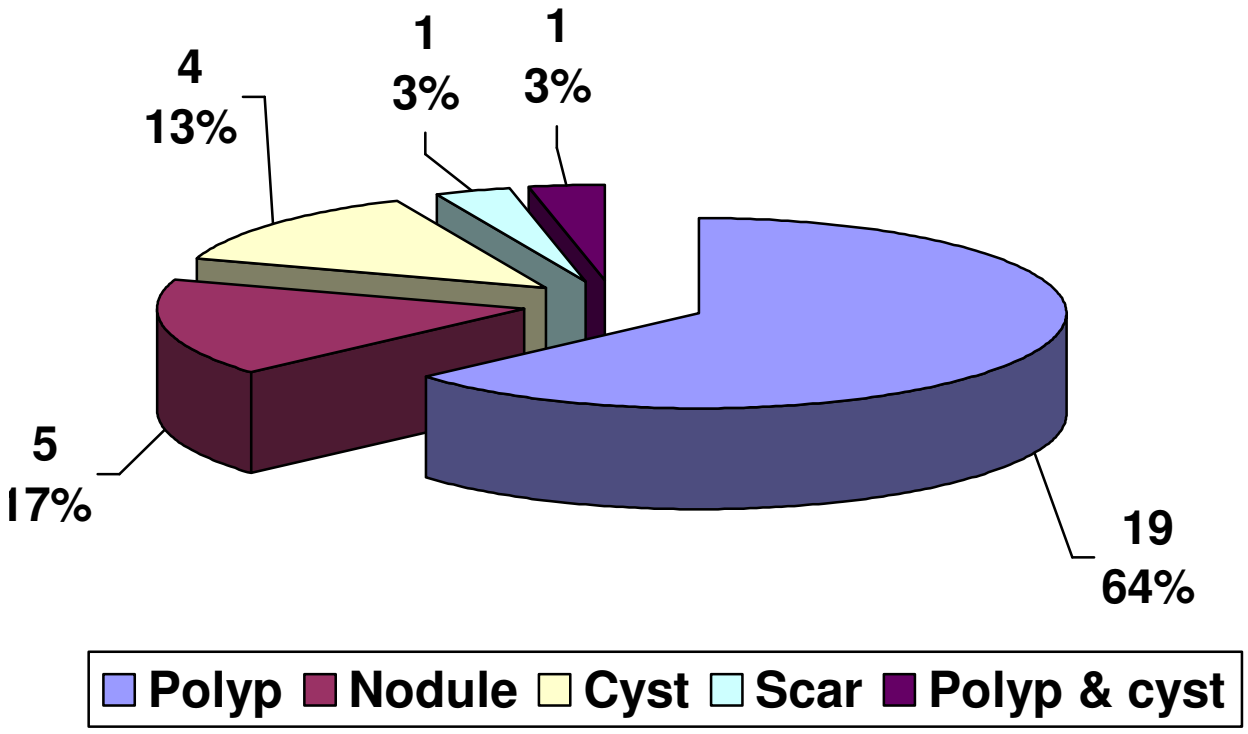

Fig 19 Prevalence of lesions.

Side and site of vocal cord lesions:

Of the 30 patients 50% (15) had a lesion on the right cord alone and 26.7%(8) had lesions on both vocal cords. Left sided lesions were 23.3% (7). Pattern of glottic closure were different for different sizes of polyps. Majority of them were hour glass type of closure (50%). (Table 3)

Table 3

Analysis of glottic closure (polyps)

	complete	Hour glass	irregular	Posterior chink
Present	4 (22.2%)	9 (50%)	7 (38.9%)	5 (27.8%)
Absent	14 (77.8%)	9 (50%)	11 (61.1%)	13 (72.2%)

Position of lesion (fig 18)

The majority of them had right cord lesions (50%) at the junction of anterior and middle third of cord (36%). Middle third lesions (30%) were more frequent than the anterior third lesions (13.3%)

Types of lesions: (fig 19)

The majority of patients had vocal polyps 19(63.3%). There was one patient with two lesions; a vocal cord polyp and a vocal cord cyst. One patient had a postoperative scar on the vocal cord.

Post operative analysis:

Symmetry:

Post operatively symmetry of the glottis on examination had risen from 2(6.7%) to 26(86.7%) in the patients.

Mucosal wave right:

On examining the mucosal wave there was an increase from 60% to 90%.

Mucosal wave left:

The left vocal cord mucosal wave was present in 26(86.7%) patients when compared to 21 patients. The predominant site of lesion on the cord was on right side.

Glottal closure:

Post operatively there was a remarkable improvement in complete glottal closure. There was an increase of 96.7% in this parameter.

Additional findings

Post operatively, the prevalence of additional findings was clearly seen, LPR showed almost the same incidence (26.7%) as pre operatively but in the case of Muscle Tension Dysphonia there was an increase from 23.3% to 33.3% Pre and post operative stroboscopic pictures Fig 20a to 20f

Acoustic analysis:

Fundamental frequency: (table 4)

In the group of 30 patients the mean fundamental frequency recorded for comfortable phonation for the group was 185.01Hz, while the speech frequency

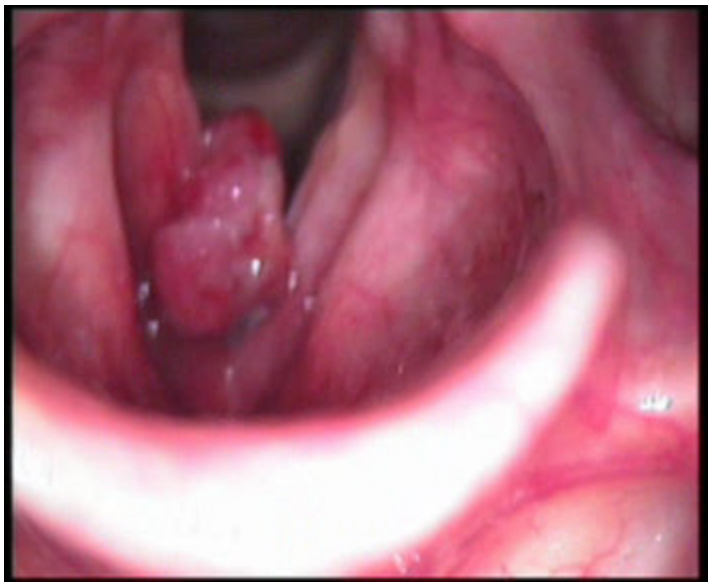

Fig 20 a (Pre op)

Fig 20b (Post op)

Fig 20c (Pre op)

Fig 20d (Post op)

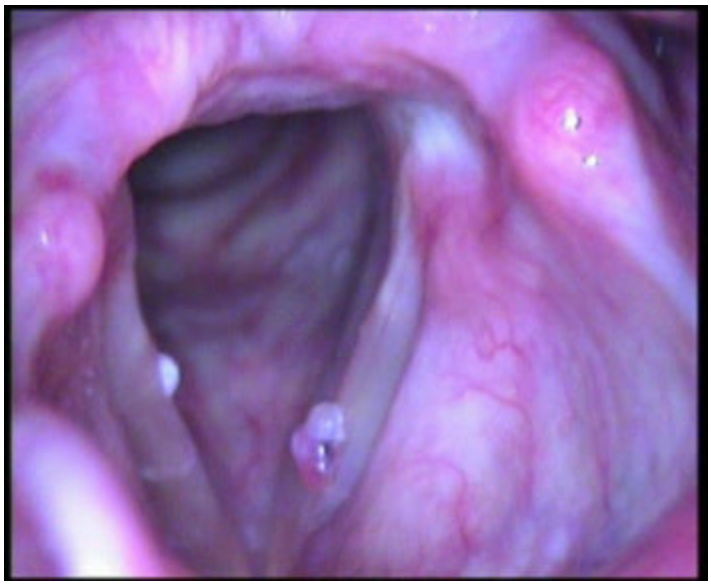

Fig 20e (Pre op)

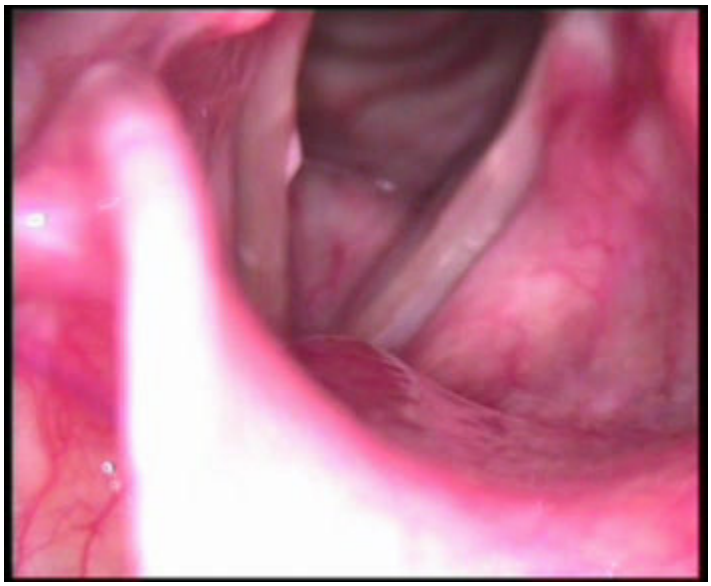

Fig 20f (Post op)

was 186.954Hz with a range of 91.634 to 291.59Hz. Similar group of people was taken as controls and their fudemental frequency were 164.644Hz with a range of 100.812 to 284.724Hz.

Table 4

Analsyis of fundamental frequency

Fundamental frequency					
	Pre operative		Post operative		
	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	180.02327	45.386437	180.963	47.2202	0.844
Low intensity /e/	188.90747	43.220789	185.463	44.7956	0.503
Low intensity /i/	183.46013	41.310574	182.887	43.2529	0.929
Comfortable intensity /a/	185.018480	44.4262674	436.555	229.285	0.326
Comfortable intensity /e/	185.583057	42.3520791	181.989	43.6904	0.499
Comfortable intensity /i/	179.30924	46.229494	175.961	50.0890	0.547
Speech	186.9543	53.26215	234.414	316.5635	0.419

Standard deviation of fundamental frequency: (table 5)

The mean value of this parameter was 2.487 when compared to the normative data of 3.276.

Table 5

Analysis of standard deviation of pitch.

Standard deviation of pitch					
	Pre operative		Post operative		
1	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	14.047287	12.8674449	6.24969	10.587316	0.008
Low intensity /e/	3.61181	7.738916	2.8806	7.14779	0.716
Low intensity /i/	3.63230	3.753797	3.93236	10.383400	0.881
Comfortable intensity /a/	2.81443	2.634070	2.61623	2.530250	0.738
Comfortable intensity /e/	2.98683	3.478013	1.97439	1.815007	0.164
Comfortable intensity /i/	3.69504	6.385359	3.11913	6.165602	0.380
Speech	8.592698	12.9705432	10.30398	12.735131	0.520

Jitter / frequency perturbation: (Table 6)

The pre operative values of jitter were found to have a mean of 2.05683%. The normal subjects had the value of 0.631 as the mean value for comfortable phonation.

Table 6

Analysis of jitter / frequency perturbation

Jitter / Frequency perturbation					
	Pre operative		Post operative		
1	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	2.56231	2.376725	2.4779%	3.40081%	0.908
Low intensity /e/	2.08965	1.952232	1.65006%	1.692141%	0.071
Low intensity /i/	2.28368	2.159819	2.079689%	2.09902%	0.482
Comfortable intensity /a/	2.05683	1.929833	4.8986%	17.3273%	0.355
Comfortable intensity /e/	2.32422	2.453738	1.74199%	1.614956%	0.095
Comfortable intensity /i/	2.31761	2.059300	2.30046%	1.74219%	0.960
Speech	2.25483	1.962776	1.75712%	1.541796%	0.145

Shimmer / amplitude perturbation: (table 7)

The shimmer value seen in patients was 3.76513% as against the 3.304% of normal data.

Table 7

Analysis of shimmer / amplitude perturbation

Shimmer / amplitude perturbation					
	Pre operative		Post operative		
1	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	3.76513	2.926170	2.9058%	2.1719%	0.048
Low intensity /e/	4.05267	2.952416	3.2694%	2.4301%	0.145
Low intensity /i/	3.84418	2.831863	3.3072%	3.6392%	0.484
Comfortable intensity /a/	3.53653	2.646932	3.3508%	2.71954	0.700
Comfortable intensity /e/	4.09778	3.698391	3.09831%	2.17426%	0.131
Comfortable intensity /i/	3.54766	3.090646	3.5911%	3.42569%	0.949
Speech	3.27875	3.143786	3.20804%	2.3872%	0.904

Harmonic to noise ratio: (table 8)

A low harmonic to noise ratio (14.357) indicating bad voice was seen pre operatively. The normative value obtained by this software was 20.996 db.

Table 8

Analysis of noise to harmonic ratio

Noise to harmonic ratio					
	Pre operative		Post operative		
1	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	14.357440	5.1757671	16.75893	4.760431	0.021
Low intensity /e/	14.8608	5.27378	17.14929	5.261784	0.048
Low intensity /i/	14.9242	6.81612	15.92878	6.699051	0.472
Comfortable intensity /a/	13.82231	5.628040	15.52070	5.611172	0.084
Comfortable intensity /e/	14.2736	5.76434	15.69991	5.396013	0.248
Comfortable intensity /i/	14.05925	6.433712	15.64056	6.745316	0.278
Speech	14.94698	4.790322	15.96748	4.747324	0.320

Voice handicap index:

Pre operative value of VHI showed a mean of 15.50, 16.97 and 11.50 for functional, physical and emotional components. The total VHI score had a mean of 43.9333.

Post operative analysis:

Stroboscopic parameters: (table 9)

Analysis was carried out using McNemar's test.

Symmetry

Vocal cord symmetry improved remarkably from 0% to 86.7%. This was statistically significant ($p < 0.0001$).

Glottic closure

A complete return of glottic closure was obtained post operatively, which gave a statistically significant p value of less than 0.0001

Mucosal wave right and left:

The improvement of mucosal wave in right and left cords were statistically significant. ($p=0.01$ & 0.016)

Table 9

Post operative stroboscopic analysis:

	Present Pre op	Present Post op	McNemar's test P value
Symmetry	2	26	<0.0001
Mucosal wave (right)	17	27	0.001
Mucosal wave (left)	21	26	0.016
Glottic closure	0	29	<0.0001

Acoustic analysis:

The analysis was done by paired 't' test.

Fundamental frequency:

Post operative analysis showed minimal deviation from the pre operative value. The value changed from 180.02327 to 180.963.

Standard deviation of fundamental frequency:

The values obtained on monovariable analysis had very minimal variations.

Jitter / frequency perturbation:

The post operative analysis of values showed a trend towards improvement.

Shimmer / amplitude perturbation:

There was mild decrease in the value compared to the pre operative data.

Harmonic to noise ratio:

Marginal increases in the post operative values were seen; indicating improvement of voice post surgical treatment.

Statistical analysis of acoustic analysis was done using the “paired t test”. The parameters which showed statistically significant improvement between pre and post operative values were,

1. Standard deviation pitch in low intensity /a/ (p value of 0.008),
2. Shimmer in low intensity /a/ (p value of 0.048),
3. Harmonic to noise ratio for low intensity /a/ (p value of 0.021) and
4. Harmonic to noise ratio for low intensity /e/ (p value of 0.048)

Sub group analysis:

Sex analysis: The number of female subjects was low; a detailed analysis was not performed. The significant values obtained were, standard deviation of pitch for low phonation of /a/ and /e/. (p= 0.002 and 0.026 respectively). The p value for shimmer (low /o/) was 0.039. However in the female subjects, fundamental frequency /e/ was significantly different (p=0.024).

The largest group of lesions were polyps (n=19). The voices recorded for these patients were analyzed separately. We found that shimmer for low intensity /i/ had statistically significant reduction. (table 10)

Table 10

Shimmer (polyps)

Shimmer (polyps)					
	Pre operative		Post operative		
	Mean	Standard deviation	Mean	Standard deviation	
Low intensity /a/	4.14973	3.130938	3.1436	2.31606	0.081
Low intensity /e/	4.00205	2.983042	3.5724	2.56109	0.513
Low intensity /i/	4.40592	3.054375	2.7902	2.31590	0.004
Comfortable intensity /a/	4.06436	2.809712	3.5139	3.05386	0.433
Comfortable intensity /e/	4.54009	4.168161	3.3055	2.23914	0.202
Comfortable intensity /i/	3.81567	3.442950	3.7500	2.67452	0.895
Speech	3.13060	3.083258	3.6748	2.65207	0.414

Voice handicap index: (Table 11)

Post operative values for functional, physical and emotional components were 13.03, 11.73 and 5.93. The total score had a mean of 30.70. Analysis was done using 'Rather paired t test'. This analysis post operative improvement in physical and emotional sub divisions of VHI. This was found to have statistical significance (p value of 0.023 and 0.002). The overall VHI score was also found to have improvement compared to pre operative scores. (p value 0.013)

Table 11

Statistically analyzed values of VHI

Voice handicap index					
	Pre operative		Post operative		
	Mean	Standard deviation	Mean	Standard deviation	
Functional	15.50	8.245	13.03	9.159	0.243
Physical	16.97	8.019	11.73	8.546	0.023
Emotional	11.50	7.899	5.93	5.759	0.002
Total	43.9333	20.75628	30.7000	20.77656	0.013

Sub group analysis:

Male and female: (Table 12)

Males had a higher subjective perception of dysphonia compared to female subjects in this study. They also considered their voices much better after surgical treatment as seen in the values.

Table 12

VHI values

	pre operative male	post operative male	P value	Pre operative female	Post operative female	P value
Functional	17.6	12.62	0.02	10.22	14	0.42
Physical	17.9	11.4	0.01	14.78	13.11	0.69
Emotional	12.57	5.90	0.003	9.00	6.00	0.36
Total	48.19	29.67	0.002	34	33	0.93

Lesions: (Table 13)

When comparing the VHI values for patients with different etiologies; patients with polyps felt the highest degree of dysphonia compared to others.

Table 13

VHI scores of different lesions.

	polyps	nodules	others
Functional	17.53	11.14	13.50
Physical	18.53	12.86	16.75
Emotional	11.58	10.71	12.5
Total	47.58	34.7	42.75

Voice usage and VHI: (Table 14)

The VHI was calculated for groups divided according to the voice usage. It was found that; group with non professional voice users had the lowest perception of dysphonia. They had an average value of 50.75 against 46.1 and 40.88 for high and normal users. They also had high value for functional and emotional subgroups of VHI.

The statistical analysis of the group's values showed significant improvement in medium users. The significant reduction was seen in total and physical subgroup of VHI.

Table 14

Voice usage and VHI

	Grade II pre op	Grade II postop	P value	Grade III pre op	Grade III post op	P value	Grade IV Pre op	Grade IV postop	P value
Functional	13.9	15.9	0.461	21	10.75	0.05	15.83	11.8	0.325
Physical	18.7	16.4	0.525	21	8	0.006	14.88	9.75	0.145
Emotional	13.5	6.20	0.006	8.75	3.5	0.293	10.94	6.38	0.114
Total	46.1	38.5	0.297	50.75	22.25	0.000	40.88	27.94	0.138

Smokers vs non smokers: (Table 15)

There were eight smokers in our group and all of them were males. The smokers showed a higher value for VHI compared to the non smokers. The analysis showed smokers satisfaction in improvement in emotional and total scores; however non smokers were only satisfied with their improvement in emotional component.

Table 15

Smokers Vs non smokers

	pre operative smoker	post operative smoker	P value	Pre operative nonsmoker	Post operative nonsmoker	P value
Functional	19.25	14.38	0.021	14.14	12.55	0.535
Physical	18.38	10.5	0.001	16.45	12.18	0.120
Emotional	15.25	7.50	0.081	10.14	5.36	0.042
Total	52.75	32.38	0.217	40.73	30.09	0.109

Discussion

Vocal cord lesions like vocal nodules, polyps and cysts though benign are significant because they disrupt the vocal fold vibratory function causing dysphonia. Removal of lesion, restoring the vibratory function and optimizing the voice are the goals of treatment of benign vocal fold lesions. Lesions not responsive to voice therapy / medical therapy have to be excised by microlaryngeal surgery. Objective and subjective assessment of the laryngeal functions before and after surgery help to evaluate the effectiveness of the treatment. Quantification of such results also helps to compare voice outcome using different phonosurgical technique

In this study videostroboscopy, acoustic analysis and VHI scores were evaluated in 30 patients with benign lesions prior to micro laryngeal surgery and 6 weeks or later. There were 22 male (73.3%) patients while in a number of previous studies there was a female predominance[24,25,26,27,28,29,30,31]. (This could be due to the fact that women tend to ignore symptoms for a longer time). Smoking which contributes to the erythema, edema and generalized inflammation of the vocal tract was noted in the 8 male while all the female patients were non-smokers. Vocal polyps were the most common benign lesion 63.3%.

Stroboscopy was first used by Oertel in 1878 to examine the larynx. With technological advances, along with video recording equipment, Stroboscopes are now user friendly and so used more often in visualization of the vocal folds and the vibratory function. The vocal fold vibratory function was assessed by the

stroboscopic parameters, glottic closure configuration whether complete or incomplete, integrity of mucosal wave (whether normal or abnormal). The vocal fold lesions prevent a complete glottic closure. The entire patient had an incomplete glottic closure (100%). Excision of the lesion resulted in complete glottic closure in 29 patients. Complete glottic closure results in greater vocal fold contact because of a smooth edge, with generation of a greater subglotic pressure and better amplitude of cord vibration. The resulting equality of vocal fold mass and regular oscillation of each fold produces an improved voice. The mucosal wave was absent on the right in 12 while on the left it was absent in 9. Post operatively on the right cord it increased to 90% and on the left it was to 86.7%. The absence or dampening of the mucosal waves is due to the extensive involvement of the subepithelium and the superficial layer of lamina propria in vocal polyps and cyst[24]. After phonosurgery restoration of mucosal vibratory function would result in a good voice[25]. Looking at individual pathologies polyps (n=19) were the majority of lesions. The stroboscopic assessment of closure pattern showed 77.8% incomplete closure. The types of closures seen were hourglass (50%) irregular (38.9%) and posterior chink (27.8%). Analysis by Colton et al[26] showed polyps having incomplete (14%) hourglass (18%), irregular (31%) posterior chink (14%) and complete closure in (14%).

Voice quality is the subjective and patient's assessment if dysphonia is important. The VHI developed by Jacobson et al is a dysphonia specific quality of life questionnaire with good content validity and reliability[32]. The VHI score reflects the patient's perception of the problem in daily life with

reference to the patient's emotional, functional and physical activities. It can be used in evaluating the effectiveness of specific voice treatment techniques. In our study there was a decrease in the VHI total scores from 43.9 in the pre-operative status to 30.7; post-operative which was statistically significant. Each of the sub scales also showed a reduction in scores though only the physical and emotional sub scales were statistically significant. In a retrospective review Behrman et al[31] suggested that the amount of vocal demand in accordance to patient's life style and occupation would influence VHI score. Routine voice users had significantly lower VHI scores than those with the high vocal demands.

The patients were categorized to elite users (n=0), professional voice users (n=10), non professional voice users (n=4) and non professional non voice users (=16) in this study; even though a trend towards improvement is same postoperatively majority of statistical evaluation showed no significance. Among the patient with non professional non voice users statistically significant improvement seen in harmonics to noise ratio /e/ (p=0.025). Among the patients with professional voice demand jitter/e/ (p=0.042) and harmonics to noise ratio /a/ (p=0.024) were found to be statistically significant. However in non professional voice user patients statistically significant improvement was seen in shimmer /a/ (p=0.024). Overall the VHI scores were low benign mucosal lesion tend to result in milder voice disorder compared to neurological disorder[33].

The acoustic analysis was done using PRAAT programme created by Paul Boersma and David Weenik of the Institute of Phonetics Sciences of the University of Amsterdam. Analysis of a sustained tone reveals fundamental

frequency (Fo), the average pitch measured in hertz (Hz). The average fundamental frequency for males is 100-150 Hz and for female it is 190- 250 Hz. However, the standard pitch range is 75-600 Hz in the PRAAT programme. Voices associated with chronic vocal abuse, misuse or vocal mass lesion has a low fundamental frequency. In the study the pre operative fundamental frequency was 176Hz for normal intensity /a/ and females was 205.65Hz. In the post operative status fundamental frequency for males was 175.365Hz and females was 206.2Hz, which didn't show any significant change. Frequency perturbation of jitter is due to instability of the cord dummy vibration and correlate to a periodicity of vocal cord vibration. The jitter in pre operative status was greater than 2.05% (1.040% is the threshold for pathology in PRAAT) and correlates to the subjective sound of hoarseness. Post operative jitter was reduced except for sustained /a/ at the comfortable pitch and loudness. Shimmer is the amplitude perturbation and was above the threshold for pathology (3.810%) except for soft /a/ in pre operative evaluation. Post operative shimmer was below 3.59%. Normal voices have low levels of noise while abnormal voices show greater noise levels. Hoarse speakers will have harmonicity (using PRAAT) much lower than 20dB. Harmonics to noise ratio was ≤ 14.9dB pre operatively which improved post operatively (>15.5dB).

The voicing, jitter and shimmer measurements made by PRAAT cannot always be compared directly with those made by other programmes and this was a limitation in this study.

Secondary MTD is caused by glottal insufficiency; this could be either due to a mass lesion or paralysis. There was an increase in MTD noted in the post operative cases examined when compared to the pre operative patients. The importance of speech therapy sessions could not be overemphasized. In our set up when patients are coming from all over the country; the compliance with the prescribed speech therapy exercises is often absent. This could be the reason for an increase of MTD in post operative patients.

In conclusion, pre and post operative assessment of patients with benign vocal cord lesions by stroboscopy, acoustic analysis, and voice handicap index is a useful way to assess the degree of improvement following surgery. Both subjective and objective parameters are assessed. Both the patient and surgeon are provided with a definitive evaluation with respect to the benefit following surgery and speech therapy.

Conclusion

1) The vibratory pattern of the vocal cords improved evidenced by the stroboscopic parameters symmetry, mucosal wave and glottic closure.

2) The voice quality parameters assessed by acoustic analysis showed an improvement following surgery. Significant improvement was noted only in Standard deviation pitch in low intensity /a/, Shimmer in low intensity /a/, harmonic to noise ratio for low intensity /a/, harmonic to noise ratio for low intensity /e/.

3) The Voice handicap index, reflecting the patient's perception of the voice problems showed a decrease in scores post operatively.

Bibliography

1) Henick DH. Laryngeal development. In: Rubin Js, Stataloff RT, Korovin GS. Diagnosis and treatment of voice disorders. Second edition. Delmar learning: 2003.2. 17-26

2) Neil W. Anatomy of larynx and tracheo bronchial tree. In. Gleeson M . Scott brown. Sixth edition. Butterworth Heinemann; 1997.1(12).1-18

3) Hirano M. surgical anatomy and physiology of vocal folds,In: Gould WJ, Satalof RT, Spiegel JR. Voice surgery. Mosby: 1993. 6.156.

4) Saski CT, Kim YH; Anatomy of human larynx. In: Rubin JS, Satatlof RT, Korovin GS. Second edition Diagnosis and treatment of voice disorders. Delmar learning; 2003. 27-38

5) Understanding voice problems, a physiological perspective for diagnosis and treatment Second edition; Colton RH, Casper FK; Williams and wilkings; 1996. 3.59-63.

6) Zemlin WR. Phonation. In: Dragin SB. Speech and hearing signs, anatomy and physiology. 4th edition; Editor: Allyn Bascon 1998; 3.182-183.

7) Understanding voice problems, a physiological perspective for diagnosis and treatment Second edition; Colton RH, Casper FK, Williams and wilkings; 1996;10.326

8) Woodson GE. Laryngeal and pharyngeal function. In: Cummings CW. Otolarygnolgy and head and neck surgery, fourth edtion. Elsevier mosby 2005.3(3).1970-1973

9) Satalof RT, Functional anatomy and physiology of voice. In: Gould WJ, Satalof RT, Spiegel JR. Voice surgery. Mosby. 1993.6.165-171

10) Koufmann JA Issacson G. The spectrum of voice dysfunction. Otolarngol clin NA; 1991.24 (5).986

11) Rosen CA, Murray T: Nomenclature of voice disorders in vocal pathology. Otolaryngol clin NA 2000; 33 (5).1035-1045

12) Fourcin A, McGlashan J, Huckvale M. The generation and reception of speech.In: Gleesnon M. Scott brown. Butterworth Heimemann; 1997 1(14).1-4

13) Jacobson BH, Johson A; The voice handicap index development and validation. American journal of speech language pathology; 1997 6: 66-70

14) Wilson JA, Webb A, Carding PN, Steen IN, Mackenzie K, Deary IJ, Voice symptom scale and vocie handicap index, a comparison of structure and content. Clinical otolaryngol. 2004; 29:169-174

15) Rosen CA, Lee AS, Osborne J, Zullo T, Murry T. Development and validation of voice handicap index 10: Laryngoscope. 2004;114:1549-1556

16) Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning; 2003.6.76

17) Gray SD, Hammod E, Hanson DF. Benign pathological response of the larynx. Annals of otology rhinology, laryngology. 1995;104:13-18

18) Kleinasasser O. Microlaryngoscopy and endolaryngeal microsurgery. third edition. Mosby inc 1991.46-47

19) Rubin JS, Yanagisawa E. Benign vocal fold pathology throught the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS. Diagnosis and treatment of voice disorders second edition; Thomson Delmar learning publisher;2003.6.75-76

20) Kleinasasser O. Microlaryngoscopy and endolaryngeal microsurgery. third edition. mosby inc 1991.46-47

21) Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning;2003.6.78

22) Damste PH. Disorders of the voice. In: Hibbert J.Scot brown otolaryngology sixth edition : Butterworth Heinemann. 1997.5(6).14-15

23) Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning; 2003.6.76-77

24) Rosen CA, Lombard LE, Murray T. Acoustic, aerodynamic, and videostroboscopic features of bilateral vocal fold lesions. Annals of otol rhinol laryngol. 2000;109:823 - 828

25) Woo P, Casper J, Colton R, Brewer D. Aerodynamic and stroboscopic findings before and after microlaryngeal phonosurgery. Journal of voice. 1994; 8:186-194

26) Colton RH, Woo P, Brewer DW, Griffing B, Casper J. Stroboscopic signs associated with Benign lesions of the vocal folds. Journal of Voice. 1995; 9: 312-325

27) Hsiung MW. Videolaryngostroboscopic observation of mucus layer during vocal cord vibration in patients with vocal nodules before and after surgery. Acta otolaryngol. 2004; 124: 186- 191

28) Noordzij JP, Woo P. Glottal area waveform analysis of benign vocal fold lesions before and after surgey. Annals of otol rhinol laryngol. 2000; 109: 441-446

29) Deary IJ, Webb A, Mackenzie K, Wilson JA, Carding PN. Short, self-report voice symptom scales: Psychometric characteristics of the Voice Handicap Index-10 and the Vocal Performance. Otolaryngol head and neck surgery.2004; 131(3):232-235

30) Speyer R, Wienneke GH, Dejonckere PH. Self assessment of voice therapy for chronic dysphonia. Clincal otolaryngol. 2004; 29: 66-74

31) Behrman A, sulica L, He T. Factors predicting patient perception of dysphonia caused by benign vocal fold lesions. Laryngoscope. 2004; 114: 1693-1699

32) Jacobson BH, Johnson A, Grywalski C, Silbergleit A, Jacobson G, Benninger MS, et al. The voice handicap index development and validation. American Journal of Speech language pathology. 1997; 6: 66-70

33) Murry T, Rosen CA. Outcome measurement and quality of life in voice disorders. Otoloaryngol clin NA. voice disorders and phonosurgery I. 2000;33: 905-916

[1] Henick DH. Laryngeal development. In: Rubin Js, Stataloff RT, Korovin GS. Diagnosis and treatment of voice disorders. Second edition. Delmar learning: 2003.2. 17-26
[2] Neil W. Anatomy of larynx and tracheo bronchial tree. In. Gleeson M . Scott brown. Sixth edition. Butterworth Heinemann; 1997.1(12).1-18
[3] Hirano M. surgical anatomy and physiology of vocal folds,In: Gould WJ, Satalof RT, Spiegel JR. Voice surgery. Mosby: 1993. 6.156.
[4] Saski CT, Kim YH; Anatomy of human larynx. In: Rubin JS, Satatlof RT, Korovin GS. Second edition Diagnosis and treatment of voice disorders. Delmar learning; 2003. 27-38
[5] Understanding voice problems, a physiological perspective for diagnosis and treatment Second edition; Colton RH, Casper FK; Williams and wilkings; 1996. 3.59-63.
[6] Zemlin WR. Phonation. In: Dragin SB. Speech and hearing signs, anatomy and physiology. 4th edition; Editor: Allyn Bascon 1998; 3.182-183.
[7] Understanding voice problems, a physiological perspective for diagnosis and treatment Second edition; Colton RH, Casper FK, Williams and wilkings; 1996;10.326
[8] Woodson GE. Laryngeal and pharyngeal function. In: Cummings CW. Otolarygnolgy and head and neck surgery, fourth edtion. Elsevier mosby 2005.3(3).1970-1973
[9] Satalof RT, Functional anatomy and physiology of voice. In: Gould WJ, Satalof RT, Spiegel JR. Voice surgery. Mosby. 1993.6.165-171
[10] Koufmann JA Issacson G. The spectrum of voice dysfunction. Otolarngol clin NA; 1991.24 (5).986
[11] Rosen CA, Murray T: Nomenclature of voice disorders in vocal pathology. Otolaryngol clin NA 2000; 33 (5).1035-1045
[12] Fourcin A, McGlashan J, Huckvale M. The generation and reception of speech.In: Gleesnon M. Scott brown. Butterworth Heimemann; 1997 1(14).1-4
[13] Jacobson BH, Johson A; The voice handicap index development and validation. American journal of speech language pathology; 1997 6: 66-70
[14] Wilson JA, Webb A, Carding PN, Steen IN, Mackenzie K, Deary IJ, Voice symptom scale and vocie handicap index, a comparison of structure and content. Clinical otolaryngol. 2004; 29:169-174
[15] Rosen CA, Lee AS, Osborne J, Zullo T, Murry T. Development and validation of voice handicap index 10: Laryngoscope. 2004;114:1549-1556
[16] Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning; 2003.6.76
[17] Gray SD, Hammod E, Hanson DF. Benign pathological response of the larynx. Annals of otology rhinology, laryngology. 1995;104:13-18
[18] Kleinasasser O. Microlaryngoscopy and endolaryngeal microsurgery. third edition. mosby inc 1991.46-47
[19] Rubin JS, Yanagisawa E. Benign vocal fold pathology throught the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS. Diagnosis and treatment of voice disorders second edition; Thomson Delmar learning publisher;2003.6.75-76
[20] Kleinasasser O. Microlaryngoscopy and endolaryngeal microsurgery. third edition. mosby inc 1991.46-47
[21] Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning;2003.6.78
[22] Damste PH. Disorders of the voice. In: Hibbert J.Scot brown otolaryngology sixth edition : Butterworth Heinemann. 1997.5(6).14-15
[23] Rubin JS, Yanagisawa E. Benign vocal fold pathology through the eyes of the laryngologist. In: Rubin JS, Satalof RT, Korovin GS;. Diagnosis and treatment of voice disorders. Second edtion. Thomson Delmar learning; 2003.6.76-77

[24] Rosen CA, Lombard LE, Murray T. Acoustic, aerodynamic, and videostroboscopic features of bilateral vocal fold lesions. Annals of otol rhinol laryngol. 2000;109:823 - 828
[25] Woo P, Casper J, Colton R, Brewer D. Aerodynamic and stroboscopic findings before and after microlaryngeal phonosurgery. Journal of voice. 1994; 8:186-194

[26] Colton RH, Woo P, Brewer DW, Griffing B, Casper J. Stroboscopic signs associated with Benign lesions of the vocal folds. Journal of Voice. 1995; 9: 312-325

[27] Hsiung MW. Videolaryngostroboscopic observation of mucus layer during vocal cord vibration in patients with vocal nodules before and after surgery. Acta otolaryngol. 2004; 124: 186- 191

[28] Noordzij JP, Woo P. Glottal area waveform analysis of benign vocal fold lesions before and after surgey. Annals of otol rhinol laryngol. 2000; 109: 441- 446

[29] Deary IJ, Webb A, Mackenzie K, Wilson JA, Carding PN. Short, self-report voice symptom scales: Psychometric characteristics of the Voice Handicap Index-10 and the Vocal Performance. Otolaryngol head and neck surgery.2004; 131(3):232-235

[30] Speyer R, Wienneke GH, Dejonckere PH. Self assessment of voice therapy for chronic dysphonia. Clincal otolaryngol. 2004; 29: 66-74

[31] Behrman A, sulica L, He T. Factors predicting patient perception of dysphonia caused by benign vocal fold lesions. Laryngoscope. 2004; 114: 1693-1699

[32] Jacobson BH, Johnson A, Grywalski C, Silbergleit A, Jacobson G, Benninger MS, et al. The voice handicap index development and validation. American Journal of Speech language pathology. 1997; 6: 66-70

[33] Murry T, Rosen CA. Outcome measurement and quality of life in voice disorders. Otoloaryngol clin NA. voice disorders and phonosurgery I. 2000;33: 905-916

Proforma

Name Age

Sex

Occupation

Address

Hospital number:

Consent form:

Complaint Duration

Voice abuse

LPR

Smoking

Diagnosis

Surgery date Follow up date

NPL scopy report

Stroboscopic parameters.

Symmetry

Mucosal wave right

Left

Glottic closure

Acoustic analysis

1. Fundamental frequency

2. Standard deviation of fundamental frequency

3. Jitter

4. Shimmer

5. Harmonic to noise ratio

	Sound 1	Sound 2	Sound 3	Sound 4	Sound 5	Sound 6	speech
1							
2							
3							
4							
5							

Voice handicap index

Functional

Physical

Emotional

Total

Date:

Post operative

Stroboscopy

Symmetry

Mucosal wave right

Left

Glottic closure

Acoustic analysis

1. Fundamental frequency

2. Standard deviation of fundamental frequency

3. Jitter

4. Shimmer

5. Harmonic to noise ratio

	Sound 1	Sound 2	Sound 3	Sound 4	Sound 5	Sound 6	speech
1							
2							
3							
4							
5							

Voice handicap index

Functional

Physical

Emotional

Total

Date:

Voice handicap index:

Instructions: These are statements that many people have used to describe their voices and the effects of their voices on their lives. Circle the response that indicates how frequently you have the same experience.

0 _ Never 1 _ Almost Never 2 _ Sometimes 3 _ Almost Always 4 _ Always

Part I: Functional

F1 My voice makes it difficult for people to hear me. 0 1 2 3 4

F2 People have difficulty understanding me in a noisy room. 0 1 2 3 4

F3 My family has difficulty hearing me when I call them throughout the house. 0 1 2 3 4

F4 I use the phone less often than I would like to. 0 1 2 3 4

F5 I tend to avoid groups of people because of my voice. 0 1 2 3 4

F6 I speak with friends, neighbors, or relatives less often because of my voice. 0 1 2 3 4

F7 People ask me to repeat myself when speaking face-to-face. 0 1 2 3 4

F8 My voice difficulties restrict personal and social life. 0 1 2 3 4

F9 I feel left out of conversations because of my voice. 0 1 2 3 4

F10 My voice problem causes me to lose income. 0 1 2 3 4

Part II: Physical

P1 I run out of air when I talk. 0 1 2 3 4

P2 The sound of my voice varies throughout the day. 0 1 2 3 4

P3 People ask, “What’s wrong with your voice?” 0 1 2 3 4

P4 My voice sounds creaky and dry. 0 1 2 3 4

P5 I feel as though I have to strain to produce voice. 0 1 2 3 4

P6 The clarity of my voice is unpredictable. 0 1 2 3 4

P7 I try to change my voice to sound different. 0 1 2 3 4

P8 I use a great deal of effort to speak. 0 1 2 3 4

P9 My voice is worse in the evening. 0 1 2 3 4

P10 My voice “gives out” on me in the middle of speaking. 0 1 2 3 4

Part III: Emotional

E1 I am tense when talking to others because of my voice. 0 1 2 3 4

E2 People seem irritated with my voice. 0 1 2 3 4

E3 I find other people don’t understand my voice problem. 0 1 2 3 4

E4 My voice problem upsets me. 0 1 2 3 4

E5 I am less outgoing because of my voice problem. 0 1 2 3 4

E6 My voice makes me feel handicapped. 0 1 2 3 4

E7 I feel annoyed when people ask me to repeat. 0 1 2 3 4

E8 I feel embarrassed when people ask me to repeat. 0 1 2 3 4

E9 My voice makes me feel incompetent. 0 1 2 3 4

E10 I am ashamed of my voice problem. 0 1 2 3 4

functional	physical	Emotional	Total

Legend for master chart

Male : 1Female : 2

Periodicity Present: 1 Absent :2

South 1 north 2 east 3

Symmetry: present: 1 absent : 2

Mucosal wave: present: 1 absent : 2 hyprekinetic: 3

Glottal area closure: complete: 1 incomplete: 2

Non vibrating segment present : 1 absent : 2 scarring: 3

Side of lesion Right: 1 left : 2 both: 3 NA: 4

Additional findings: not applicable: 1 GERD: 2 MTD : 3

Position of lesion: anterior third: 1 middle third : 2 posterior third: 3 anterior middle junction : 4 superior surface: 5 not applicable: 6

Lesions: polyp: 1 cyst: 2 nodule: 3 not applicable: 4 scar: 5

Present is 1 and absent is 2

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1		hosp numb	sex	occupation	age	location	duration	voice abus	smoking	LPR	periodicity	Symmetry	Mucosalwa	Mucosal wa
2	1	752627c	1	4	28	2	45	2	1	2	1	2	1	2
3	2	729254c	1	4	47	2	36	1	1	2	2	2	1	2
4	3	633918c	2	2	49	1	5	2	2	2	2	2	2	1
5	4	768773c	1	2	31	2	24	1	2	2	2	2	1	1
6	5	750924c	1	4	32	2	30	1	1	2	1	2	2	2
7	6	737968c	2	4	27	1	12	1	2	2	2	2	1	2
8	7	654837c	2	4	27	1	13	1	2	2	1	2	1	2
9	8	715190c	2	2	43	1	2	1	2	2	1	2	1	1
10	9	737968c	1	3	38	1	1	1	1	2	1	2	2	1
11	10	732367c	1	4	38	2	12	2	1	2	2	2	2	1
12	11	732614c	1	4	44	2	3	1	2	2	1	2	3	1
13	12	710578C	1	2	46	3	2	1	2	2	1	2	1	1
14	13	735327c	1	3	62	2	2	2	2	1	2	1	1	1
15	14	766453c	1	2	28	1	12	1	2	2	2	2	1	1
16	15	657169a	1	4	54	1	5	2	2	2	2	1	1	1
17	16	766333c	2	4	19	2	6	1	2	2	2	2	2	1
18	17	744649c	1	2	20	1	3	1	2	2	1	2	1	1
19	18	822244c	1	4	27	2	24	1	2	2	1	2	1	2
20	19	824366c	2	4	35	2	2	2	2	2	1	2	1	1
21	20	728451c	1	2	31	2	12	1	2	2	2	2	2	1
22	21	772790c	1	4	18	1	6	2	2	2	2	2	1	2
23	22	828782c	2	4	40	2	36	1	2	2	2	2	2	2
24	23	768997c	1	4	48	2	6	1	2	2	1	2	1	1
25	24	740409c	1	4	38	2	6	1	2	2	1	2	2	1
26	25	752516C	1	2	43	2	2	2	1	2	2	2	2	1
27	26	829731c	1	3	32	2	28	1	1	2	2	2	1	2
28	27	174215c	1	2	43	2	4	2	2	1	2	2	2	1
29	28	766547c	1	3	40	2	3	1	1	2	1	2	1	1
30	29	824176c	1	2	36	2	6	1	2	2	2	2	2	1
31	30	743169c	2	4	32	2	6	2	2	2	2	2	2	1

	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB
1	Glottal clos	side of lesi	position of	additional f	lesions	MEAN PIT(	MEAN PIT(	MEAN PIT(	MEAN PIT(	MEAN PIT(	MEAN PIT(	MEAN PIT(	standard d	standard d
2	2	2	2	2	1	183.946	196.236	190.422	178.4398	198.4387	178.533	198.42	0.3274	1.683
3	2	3	3	1	1,2	98.467	130.522	109.774	133.977	132.22	93.235	134.769	24.158	42.463
4	2	1	4	1	2	198.347	200.423	187.432	198.733	220.543	187.38	221.004	1.9872	2.5782
5	2	1	4	3	1	189.334	190.63	210.47	198.432	185.893	202.213	197.234	12.468	1.4324
6	2	3	3	1	1	165.28	174.4	164.69	184.328	174.455	158.89	187.664	15.239	1.5683
7	2	2	3	1	1	206.63	187.2	187.4	202.4	186.4	188.044	198.3	11.566	1.384
8	2	2	3	1	5	205.832	198.478	189.98	220.357	198.56	179.55	168.56	41.745	1.9567
9	2	3	3	1	3	213.149	240.941	114.71	192.52	197.503	109.463	253.821	1.454	1.205
10	2	1	3	2	1	116.832	181.669	197.045	150.139	149.741	153.352	198.954	40.404	13.279
11	2	1	2	1	1	140.329	138.256	143.529	126.981	137.853	138.56	157.347	21.993	1.292
12	2	1	2	2	2	124.463	186.999	181.235	91.634	100.022	103.294	142.571	11.03	1.565
13	2	2	4	1	1	143.019	156.38	178.42	155.2348	176.85	187.52	178.27	31.343	1.589
14	2	1	1	3	1	198.478	169.324	184.453	195.722	199.564	175.44	198.24	10.523	3.684
15	2	2	2	3	1	177.432	186.345	178.78	199.35	184.906	176.967	188.956	9.476	1.564
16	2	3	4	1	3	157.327	155.45	185.63	166.243	187.24	165.65	177.234	3.378	2.583
17	2	1	2	2	1	132.943	142.63	158.239	159.36	165.93	149.45	177.52	8.227	4.268
18	2	3	4	3	3	158.28	169.38	163.47	192.3478	163.66	186.786	161.765	12.237	1.363
19	2	2	2	2	1	185.78	193.68	191.478	187.378	192.68	188.93	197.88	10.472	1.483
20	2	3	4	2	3	252.224	263.67	259.37	249.67	261.47	249.74	255.68	11.33	0.373
21	2	1	1	2	1	265.96	287.79	264.89	274.57	269.57	271.57	269.723	11.484	5.383
22	2	2	4	1	2	286.37	295.64	285.89	291.59	288.59	291.59	299.49	10.373	0.364
23	2	3	2	3	3	229.9	227.654	211.873	234.872	220.981	236.1323	199.563	21.376	2.3786
24	2	1	2	1	2	171.38	189.34	176.78	179.37	188.37	173.47	186.37	0.378	0.462
25	2	1	4	1	1	199.37	210.38	203.38	199.38	192.23	221.38	202.28	12.28	0.281
26	2	1	4	3	1	165.4	156.7	157.4	156.3	165.6	176.3	4.782	3.288	1.363
27	2	3	4	1	1	210.348	211.46	210.348	209.38	210.85	207.26	209.26	1.498	0.478
28	2	1	4	3	1	119.74	121.58	120.77	117.89	120.789	121.59	118.69	33.574	1.584
29	2	1	1	1	1	187.37	184.52	189.27	185.93	187.33	186.93	187.23	0.682	1.782
30	2	1	1	1	1	115.096	119.09	109.3	117.348	113.47	120.38	116.47	44.555	1.393
31	2	1	2	2	1	201.672	200.457	197.376	200.678	195.783	199.678	220.583	2.573	5.572

	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP
1	standard d	standard d	standard d	standard d	standard d	jitter1	jitter2	jitter3	jitter4	jitter5	jitter6	jitter7	shimmerim	shimmer2
2	12.568	3.684	1.457	12.573	1.3897	2.633	3.683	1.487	4.462	5.283	3.372	5.234	5.285	1.438
3	4.783	8.029	5.026	1.925	13.818	0.374	0.903	0.037	0.092	0.384	0.037	0.393	0.268	0.238
4	12.573	3.4982	2.583	0.4871	5.769	4.684	6.238	7.384	3.1237	4.4382	2.483	3.383	5.278	1.484
5	6.348	1.683	3.397	1.4792	5.826	1.566	2.4823	1.348	2.483	0.4232	4.457	3.373	7.282	6.282
6	3.574	1.4754	4.468	2.565	14.683	1.435	0.3242	0.244	1.5235	0.382	1.436	0.832	1.483	4.435
7	1.327	1.786	2.763	1.288	2.239	1.844	1.32%	2.48%	1.37%	0.24%	0.38%	1.38%	2.48%	3.44%
8	1.566	2.454	2.636	1.784	1.945	2.454	1.868	1.675	2.573	1.5636	2.464	2.483	2.483	5.912
9	5.583	4.202	1.884	33.58	20.128	0.733	0.472	0.483	0.072	0.036	0.02	0.383	0.047	0.892
10	3.146	8.641	16.796	1.518	21.3	0.484	0.036	0.393	0.419	0.037	0.073	0.937	0.284	0.384
11	2.613	3.258	2.281	2.144	46.6	0.044	0.093	0.483	0.484	0.089	0.393	0.937	0.362	0.923
12	1.251	1.167	1.122	0.641	14.552	0.005	0.037	0.073	0.047	0.048	0.037	0.037	0.021	0.037
13	0.731	1.574	1.675	1.245	7.353	0.364	0.385	1.354	0.528	0.341	1.456	0.072	2.767	3.337
14	5.277	2.34	1.473	3.2342	1.123	5.355	4.583	6.382	5.382	8.343	5.283	6.422	8.822	5.293
15	11.455	1.473	0.372	1.483	0.363	4.566	2.323	3.583	1.35	2.582	3.272	1.383	4.573	2.393
16	2.234	1.583	2.435	1.324	0.245	3.23	1.234	2.583	0.123	1.732	1.573	1.493	2.492	5.16
17	3.257	2.794	1.4783	2.842	6.635	2.111	3.379	2.157	1.849	2.624	5.256	2.382	7.721	6.383
18	1.9874	0.473	2.376	3.582	12.2397	3.876	2.483	3.774	4.683	5.382	5.931	4.282	6.237	7.254
19	11.573	2.473	1.376	12.68	0.384	1.584	2.583	1.583	3.583	5.282	2.483	3.478	2.484	1.383
20	0.373	12.47	1.496	0.474	0.346	0.168	0.474	2.483	0.572	0.473	2.483	1.383	2.145	4.473
21	4.474	2.03	1.682	3.482	1.594	5.238	5.292	4.792	4.284	3.703	5.473	2.489	11.58	12.48
22	0.936	0.451	0.927	1.502	0.491	6.383	5.283	7.373	6.924	7.371	5.292	5.392	7.383	8.373
23	0.2365	3.7863	5.2876	1.3897	1.384	0.786	1.89789	1.2345	2.287	1.376	1.589	3.345	4.7652	4.278
24	1.478	2.348	0.372	1.668	1.912	1.383	2.361	1.371	0.997	1.388	0.1572	1.372	2.99	7.44
25	0.362	1.237	1.056	0.371	1.993	1.994	1.03	0.992	1.835	1.229	1.927	2.278	4.262	7.272
26	2.279	3.379	4.782	4.897	1.37%	0.37%	1.36%	1.39%	1.38%	2.35%	0.37%	3.39%	2.35%	1.48%
27	0.489	0.73	0.82	0.647	53.493	6.2398	7.236	6.348	6.093	7.355	6.983	7.347	6.933	7.583
28	0.458	2.594	1.68	0.547	0.572	1.594	0.483	0.387	0.332	0.347	1.494	0.348	3.494	2.493
29	0.772	1.626	1.838	1.323	2.17	10.28	0.476	0.382	0.885	1.473	0.366	0.511	0.581	2.581
30	1.582	0.472	1.483	2.593	0.483	2.511	0.786	1.578	0.484	0.873	1.498	0.578	4.62	3.883
31	3.683	0.722	12.583	5.583	15.383	2.583	1.583	2.683	1.484	2.583	1.483	0.332	1.483	2.582

	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD
1	shimmer3	shimmer4	shimmer5	shimmer6	shimmer7	harmonic t	harmonic t	harmonic t	harmonic t	harmonic t	harmonic t	harmonic t	VHI1	VHI2
2	3.483	2.348	1.489	2.483	1.383	11.4832	12.58	10.68	11.383	14.37	11.734	10.732	19	19
3	0.038	0.034	0.037	0.037	0.393	3.582	6.254	3.707	10.364	5.068	4.23	6.927	18	4
4	2.483	3.383	5.347	3.382	4.283	11.423	15.452	13.568	19.324	17.373	12.4324	10.834	5	13
5	7.349	6.455	15.373	6.383	5.283	15.532	14.58	15.47	13.435	21.489	28.546	17.944	21	24
6	2.536	2.842	3.9467	6.345	4.328	11.454	12.455	11.63	10.453	14.346	11.377	18.546	26	25
7	3.44%	5.29%	2.29%	1.40%	2.49%	12.499	6.238	3.474	11.244	7.987	5.874	15.979	26	25
8	2.453	3.452	3.384	2.921	3.348	11.943	3.4543	5.734	12.38	5.383	4.862	11.952	1	3
9	0.439	0.049	0.035	0.198	0.933	17.844	21.479	6.739	16.17	13.509	3.002	15.501	15	17
10	0.864	0.118	0.191	0.384	0.056	10.525	18.263	31.721	9.682	4.382	19.473	15.666	9	12
11	0.038	0.903	0.838	0.037	0.037	7.832	10.635	11.694	1.952	5.502	7.669	7.878	17	23
12	0.045	0.038	0.036	0.037	0.934	19.008	17.084	29.402	2.385	9.154	17.134	10.911	3	3
13	4.405	2.345	9.373	1.4923	0.233	21.957	23.68	22.69	24.734	19.821	22.737	24.842	17	22
14	7.576	8.382	3.242	4.483	2.342	13.843	15.411	13.63	11.483	12.393	15.734	12.45	7	4
15	3.382	1.348	3.473	1.392	2.582	16.625	16.568	15.633	11.4353	14.484	15.5121	11.734	12	23
16	3.062	3.234	3.851	2.493	3.268	16.83	11.46	16.832	15.269	19.942	15.456	17.832	7	14
17	8.736	6.374	4.733	6.633	2.455	16.863	18.836	19.762	17.835	19.734	17.269	17.845	8	20
18	6.264	3.682	6.274	7.583	12.693	13.258	16.388	13.5763	14.733	15.893	17.523	16.134	18	23
19	2.382	1.348	0.037	2.483	0.373	12.348	13.34	17.38	11.347	14.383	11.484	14.482	19	4
20	4.473	2.584	4.363	3.474	2.458	26.259	22.45	21.473	24.68	23.58	22.484	22.484	12	15
21	11.58	10.458	12.483	14.484	12.48	12.45	13.48	14.041	12.91	14.483	16.39	12.819	31	25
22	6.282	7.383	8.39	6.392	5.393	4.493	6.393	5.02	7.194	6.119	5.997	8.333	19	29
23	3.376	3.289	2.2348	3.237	2.489	17.286	18.376	17.1289	16.237	18.239	14.237	16.2183	7	14
24	2.698	1.745	2.72	4.178	2.689	17.376	18.27	17.234	18.92	16.493	19.234	17.55	27	22
25	5.272	5.276	5.772	4.772	5.112	22.292	21.38	21.282	23.23	19.222	24.233	21.398	21	14
26	3.40%	4.79%	3.38%	4.29%	2.61%	13.376	12.387	13.786	14.344	22.388	6.376	8.379	16	25
27	8.333	7.383	8.489	7.283	8.38	7.36	8.399	7.923	8.376	6.933	8.335	7.993	22	18
28	3.594	4.392	3.504	2.505	3.503	16.349	15.39	17.408	17.393	15.695	15.65	19.604	21	22
29	0.482	1.723	0.712	0.481	0.893	21.893	22.72	21.836	21.79	22.89	20.792	21.68	27	21
30	4.382	2.996	4.458	3.69	2.45	10.448	18.873	15.69	13.505	14.606	12.509	19.48	14	23
31	2.483	2.4582	2.482	1.482	2.492	16.292	13.548	11.583	10.482	12.348	13.492	14.282	0	3

	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP	BQ	BR
1	VHI3	vhi total	periodicity1	Symmetry1	Mucosalwa	Mucosal wa	Glottal area	side of lesi	position of	additional f	lesions	MEAN PIT	MEAN PIT	MEAN PIT
2	10	48	1	1	1	1	1	4	6	1	4	148.4	140.4	143.5
3	24	46	2	2	1	1	1	1	2	1	2	100.58	101.48	99.38
4	4	22	1	1	2	1	1	4	6	1	4	221.423	220.42	198.324
5	16	61	2	1	1	1	1	4	6	1	5	98.23564	123.576	100.476
6	20	71	1	1	1	1	1	4	6	2	4	178.5	156.5	156.3
7	25	76	1	2	1	2	2	2	3	1	5	205.832	198.478	189.98
8	1	5	1	1	1	2	1	2	3	1	5	204.72	200.23	199.378
9	10	42	1	1	1	1	1	4	6	1	4	213.1	240.9	114.7
10	13	34	1	1	1	1	1	4	6	2	4	141.747	143.491	154.186
11	4	43	2	2	1	1	1	4	6	3	4	159.302	197.406	215.189
12	1	7	2	1	1	1	1	1	2	1	5	122.457	181.456	185.452
13	19	58	1	1	1	1	1	4	6	3	4	142.84	158.841	177.081
14	4	15	1	1			1	4	6	3	4	188.345	187.5464	178.54
15	15	50	1	1			1	4	6	3	5	187.232	179.566	195.45
16	7	28	1	1	1	1	1	4	6	1	4	159.38	167.483	175.68
17	8	36	2	1	1	1	1	4	6	3	4	133.68	159.783	157.45
18	17	58	1	1	1	1	1	4	6	3	4	193.8	175.83	181.93
19	2	25	1	1	1	1	1	4	6	2	4	121.86	125.764	136.6
20	8	35	1	1	1	1	1	4	6	3	4	256.48	261.48	260.57
21	15	71	2	1	1	1	1	4	6	2	4	269.38	279.48	267.39
22	27	75	1	2	1	1	1	4	6	3	4	284.58	281.48	272.459
23	8	29	1	1	1	1	1	4	6	3	4	234.834	228.84	198.576
24	18	67	1	1	1	1	1	4	6	2	4	178.23	175.26	172.89
25	13	48	1	1	1	1	1	4	6	2	4	221.39	220.3	221.39
26	21	62	2	1	1	1	1	4	6	3	4	176.7	157.3	187.5
27	18	58	1	1	1	1	1	4	6	1	4	210.34	208.34	210.348
28	0	43	2	1	1	1	1	4	6	3	4	132.27	129.38	132.34
29	12	60	1	1	1	1	1	4	6	1	4	185.38	185.29	183.49
30	5	42	1	1	1	1	1	4	6	2	4	156.342	167.234	198.561
31	0	3	1	1	1	1	1	4	6	2	4	201.53	210.347	221.49

	BS	BT	BU	BV	BW	BX	BY	BZ	CA	CB	CC	CD	CE	CF
1	MEAN PIT(	MEAN PIT(	MEAN PIT(	MEAN PIT(	standard d(	standard d(	standard d(	standard d(	standard d(	standard d(	standard d(	jitter1po	jitter2po	jitter3po
2	135.4	148.4	141.4	153.8	2.498	1.38	2.488	1.374	2.379	1.374	12.487	1.40%	2.49%	1.38%
3	100.47	102.489	97.37	98.27	1.945	0.923	1.672	1.493	0.59	1.473	0.479	18.478	0.489	0.478
4	200.423	187.347	223.42	12.473	1.595	1.585	0.483	1.484	0.348	1.494	0.585	1.383	2.489	1.494
5	125,764	145.2873	104.786	135.476	12.465	40.4786	2.476	6.2373	6.276	0.3274	12.4376	3.476	1.376	0.3684
6	173.8	163.1	157.4	170.45	12.33	1.327		1.388	1.373	2.274	11.327	0.77%	0.37%	0.13%
7	220.357	198.56	179.55	168.56	41.745	1.9567	1.566	2.454	2.636	1.784	1.945	2.454	1.868	1.675
8	201.595	204.459	187.348	183.68	34.437	1.583	4.483	0.374	1.483	1.946	1	0.382	1.393	1.987
9	192.5	197.5	109.5	253.8	1.454	1.205	57.448	4.202	1.88	33.974	20.128	0.58%	0.27%	0.62%
10	124.593	133.381	138.34	146.322	1.748	0.631	1.993	1.253	1.21	1.37	13.882	0.316	0.367	0.291
11	137.672	172.178	166.781	185.947	27.398	2.729	5.646	3.485	8.62	9.875	46.835	2.195	0.335	0.374
12	91.675	103.568	103.324	157.981	1.076	0.523	1.589	0.372	1.732	1.672	15.522	0.236	0.365	0.157
13	129.569	144.688	145.612	137.66	1.759	2.275	4.655	1.434	3.575	1.379	9.315	0.422	0.353	0.464
14	186.756	186.63	175.745	166.7457	0.419	1.2342	4.6546	6.653	1.5464	3.343	1.1677	4.3242	4.1266	6.2342
15	165.567	198.345	176.567	188.345	1.6346	1.65767	3.6745	0.243	0.123	1.242	2.343	2.8034	1.966	3.324
16	167.542	178.345	167.767	177.83	1.554	1.827	1.9659	1.923	0.242	2.426	1.9435	3.183	1.366	3.841
17	166.94	161.53	149.45	169.55	5.755	1.633	2.455	2.937	1.845	2.356	5.384	3.2723	2.583	3.683
18	182.8	192.63	187.388	179.763	1.3873	2.376	1.837	3.3894	1.3873	1.3874	12.273	2.893	1.0843	1.876
19	129.34	123.542	118.64	123.4872	1.565	2.793	1.583	8.483	1.79	1.593	54.63	1.485	1.882	2.693
20	256.76	263.47	255.38	253.58	1.488	1.599	0.484	7.348	1.484	0.794	0.296	0.378	1.04	2.49
21	272.489	271.69	282.55	274.38	1.484	2.384	1.686	9.482	0.487	1.484	1.483	2.459	0.483	2.483
22	284.58	277.3	289.38	287.48	1.494	1.997	1.477	0.337	0.174	1.474	12.589	5.239	6.282	6.282
23	221.845	202.63	243.63	212.58	2.673	1.783	1.935	0.572	3.782	6.882	15.93	2.683	2.672	1.683
24	176.39	177.28	176.12	173.4	1.686	0.283	1.393	0.393	1.393	0.372	1.39	0.392	1.209	1.5622
25	225.38	227.28	221.043	223.39	0.389	0.47	0.265	1.393	0.392	0.376	1.383	0.382	0.585	0.732
26	160.4	153.9	163.9	173.5	2.46	3.988	1.373	1.327	3.897	1.384	1.348	1.32%	0.24%	0.24%
27	209.38	220.39	201.38	208.497	0.235	1.494	0.393	1.944	2.497	0.397	12.94	6.438	7.228	8.278
28	121.89	139.39	129.77	135.28	1.304	0.382	1.327	2.383	1.094	1.763	12.29	0.27	1.437	0.463
29	187.29	188.35	186.47	1886.39	1.584	0.487	1.337	1.827	1.572	1.692	19.473	1.887	0.478	0.297
30	166.529	196.53	198.34	176.42	1.4389	1.9453	1.0213	0.7121	1.834	0.376	5.6256	1.3489	2.34	5.232
31	212.59	199.48	200.478	217.39	18.49	1.49	0.678	1.59	1.59	5.29	0.34	1.489	0.347	1.583

	CG	CH	CI	CJ	CK	CL	CM	CN	CO	CP	CQ	CR	CS	CT
1	jitter4po	jitter5po	jitter6po	jitter7po	shimmer1p	shimmer2p	shimmer3p	shimmer4p	shimmer5p	shimmer6p	shimmer7p	harmonic t	harmonic t	harmonic t
2	2.77%	1.39%	1.39%	2.48%	2.33%	4.84%	1.48%	2.79%	1.39%	3.19%	5.90%	15.398	13.388	12.388
3	2.489	1.453	1.595	1.583	0.481	1.489	1.484	0.593	1.474	0.583	2.489	19.499	18.944	19.78
4	1.349	0.383	1.404	0.027	1.393	1.459	2.383	1.955	1.682	0.237	2.393	18.382	17.373	20.392
5	2.4365	0.2344	0.3876	0.052	0.9211	0.2544	0.3244	0.0973	0.2344	1.3454	0.34412	21.324	7.342	2.324
6	0.48%	1.47%	0.33%	0.29%	3.18%	4.18%	2.35%	4.18%	5.28%	3.79%	5.34%	14.475	13.436	7.398
7	2.573	1.5636	2.464	2.483	2.483	5.912	2.453	3.452	3.384	2.921	3.348	11.943	3.4543	5.734
8	1.345	1.349	1.349	0.392	1.393	0.373	1.83	2.39	0.883	0.275	0.347	21.634	22.492	21.498
9	0.85%	1.92%	4.86%	1.19%	3.75%	3.71%	18.83%	4.06%	5.05%	16.21%	5.02%	17.844	21.479	6.739
10	0.847	0.618	0.328	1.687	2.612	5.855	2.356	5.609	5.419	3.771	4.433	19.968	20.47	27.421
11	2.289	1.537	1.595	2.218	3.728	1.701	1.743	4.446	2.524	2.799	3.567	6.253	24.259	25.522
12	0.476	0.147	1.476	0.376	1.487	1.987	2.476	1.383	1.235	2.421	1.376	11.387	21.387	11.487
13	0.674	0.381	0.298	2.044	2.217	2.199	4.804	3.365	5.671	3.509	4.67	21.555	21.795	23.905
14	5.3443	4.3242	5.7464	2.2342	6.321	3.3563	5.1442	4.2424	2.425	6.342	6.242	16.677	18.232	16.3453
15	2.2131	1.234	2.1321	1.123	3.324	2.656	1.944	1.0533	2.04543	2.354	1.3267	18.25	17.5634	16.6536
16	1.3455	1.35	2.8342	3.234	1.642	2.942	2.842	1.8934	2.3545	3.178	3.831	18.324	21.435	17.45
17	1.857	3.053	4.844	2.062	4.932	5.325	7.733	2.742	4.452	6.711	4.734	17.174	18.27	16.0453
18	2.47864	1.0564	2	2.3764	2.879	3.864	2.876	5.873	4.783	3.673	2.763	15.3678	11.476	16.387
19	1.592	1.509	1.993	0.691	1.689	0.778	1.483	3.503	0.882	1.494	1.484	15.824	16.992	15.256
20	1.484	2.494	1.494	1.047	2.81	3.593	1.494	1.949	2.459	2.594	1.505	26.493	23.59	26.484
21	3.493	1.495	3.493	1.502	9.489	10.394	7.393	14.384	8.483	12.494	11.493	21.594	23.59	19.493
22	5.382	6.077	6.992	5.288	7.58	8.333	7.922	6.99	7.255	5.44	4.992	11.48	12.47	11.47
23	0.673	2.682	1.594	1.572	2.703	1.583	3.793	5.282	2.682	0.482	1.482	15.793	14.673	12.7893
24	0.282	1.873	1.973	0.373	1.327	0.876	0.273	1.393	0.282	1.387	0.226	19.37	19.375	19.35
25	0.273	1.567	1.583	1.5493	0.284	1.596	0.593	1.844	0.843	1.953	1.505	12.494	13.73	14.287
26	0.89%	1.35%	2.30%	0.25%	2.33%	2.24%	1.23%	2.24%	2.33%	3.88%	2.33%	11.328	12.239	5.333
27	96.39	7.093	6.237	7.238	5.97	6.293	6.383	5.384	6.273	6.227	5.373	5.392	8.336	6.393
28	1.488	0.387	1.882	2.994	4.822	5.282	2.48	3.482	4.232	3.29	3.329	14.492	13.923	15.285
29	0.612	0.117	1.902	0.386	0.591	0.183	0.892	0.222	0.789	1.825	1.903	21.07	21.936	21.892
30	1.2423	0.213	1.324	2.234	1.1223	2.9432	1.234	2.3243	4.324	1.98435	0.123	21.546	19.34	22.435
31	1.349	1.942	1.43	1.743	1.39	1.894	0.992	1.406	1.832	1.382	2.38	20.437	21.489	19.927

	CU	CV	CW	CX	CY	CZ	DA	DB	DE
1	harmonic to	harmonic to	harmonic to	harmonic to	VHI1po	VHI2po	VHI3po	VHI total po	
2	12.379	7.379	7.373	12.379	4	5	4	13	
3	18.38	19.89	18.234	19.005	27	21	18	66	
4	22.348	21.378	22.489	21.392	5	4	2	11	
5	5.452	5	2.242	7.39	28	28	17	73	
6	12.439	15.874	13.834	11.487	17	12	9	38	
7	12.38	5.383	4.862	11.952	1	3	1	5	
8	22.439	21.34	22.238	21.303	27	12	11	50	
9	16.17	13.509	3.002	15.501	25	13	3	41	
10	17.42	18.915	22.351	15.973	1	2	7	10	
11	2.801	12.82	11.148	10.864	3	4	2	9	
12	4.276	3.487	13.387	11.376	19	22	15	56	
13	21.208	21.832	28.264	15.354	15	26	0	41	
14	16.8575	15.363	17.46	22.43	6	5	1	12	
15	17.9056	15.63	17.463	17.345	5	5	0	10	
16	20.63	19.6523	19.6398	18.545	1	3	0	4	
17	15.93	17.942	17.721	16.2177	7	12	8	27	
18	14.489	15.86	11.387	18.32476	24	32	12	68	
19	18.783	15.27	17.38	16.384	3	5	4	12	
20	21.484	24.49	24.48	22.973	13	7	5	25	
21	18.383	17.348	17.348	18.483	23	19	17	59	
22	10.48	12.28	10.388	10.383	17	2	2	21	
23	12.782	13.682	15.782	14.926	12	14	12	38	
24	18.387	16.39	19.393	18.394	12	5	0	17	
25	12.458	13.294	12.384	14.239	14	17	2	33	
26	11.329	21.328	7.463	8.238	27	21	12	60	
27	7.356	9.83	7.455	6.493	21	7	3	31	
28	15.263	14.49	16.293	16.39	5	7	5	17	
29	21.782	21.722	21.723	21.699	15	12	5	32	
30	24.34	19.934	24.45	24.346	2	6	1	9	
31	19.29	19.744	21.583	19.238	12	21	0	33	